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Design and Development of an Enhanced Biodynamic Manikin

Phase Report I for Contract DAMD17-90-C-0116

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Manikins have been used as substitutes for human subject in biodynamic testing since 1944. The original manikin was a simple wooden form to provide an equivalent weight to body mass for testing an ejection seat in a German DO335 aircraft. Since then, manikins have undergone a gradual evolution trying to achieve the goal of a biofidelic human analog. Standard Hybrid III-type manikins have a rigid thoracic and lumbar spine, limiting the response of the manikin's back in a dynamic environment. The predominant injury in survivable U.S. Army rotary-wing mishaps often is spinal injury. The U.S. Army wants to procure a manikin with an enhanced spinal biofidelity with self-contained data acquisition and storage capabilities. The proposed evolution in manikin design to meet the needs of the Army is discussed. A standard Hybrid III-type manikin will be modified. A standard DOT part 572 head and Hybrid III flexible neck will be used. The spinal column includes a flexible spine with multiple vertebral segments, adjustment blocks, biodynamic load cells and sensors, and mountings for the neck and shoulder. Rib segments will provide 3

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inches of deformation, precluding traditional placement of the data acquisition system in the chest cavity. Therefore, a new enhanced, anatomically representative pelvis will contain a high speed, real time data acquisition and storage system (DASS-II). Nickel-cadmium battery cells in the upper legs provide battery power to the DASS-II. This report contains criteria, specifications and drawings related to these design goals.

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1.0 Background

Military pilots and crew members are periodically exposed to abrupt changes in uniform linear motion, as observed by accelerations resulting from emergency egress, parachute opening shocks, crash/impact events and blast induced effects. The type of injuries associated with these high G scenarios have been documented to include head, neck, and spinal injuries ranging from mild trauma to death. The ability to quantify the relative motion, accelerations, forces, movements and loading at specific anatomical locations (head, occipital condyles, T1, thorax and base of the lumbar spine) would provide detailed information associated with injury mechanisms and potentials; and aid in the evaluation and testing of life support and escape system/crashworthy seat equipment. Detail biodynamic response data would become the driving function for advanced seating systems, protective/restraint systems and overall cockpit design.

Researchers attempting to identify and quantify human response to transitory acceleration, have commonly utilized analog surrogates, due to limitations imposed by human testing within these environments. These analogs have included cadavers, non-human primates and manikins. The use of manikins for testing and evaluation of restraint systems, crash/impact protective systems, physiological acceptability of military material and injury potentials is well documented by the military and automotive communities. In the past, the extensive sensor and instrumentation requirements necessary to provide the six degree of freedom information required to precisely define the time history of selected anatomically correlatable points required large volumes to be dedicated as instrumentation mounting. These large volumes, and rigid mounting structures have limited the deformation characteristics of the manikin minimizing the degree of biofidelity attainable and limiting the consequent parallel to human response.

The evaluation of ejection and crashworthy seating systems has traditionally been based on track and tower tests employing instrumented dummies. The manikins function to load the seating system evaluating system performance and human tolerance. The data generated in these tests is correlated to experimental human test or cadaver data in an attempt to assess injury mechanisms and potentials, and as a validation criteria of manikin biodynamic response. A lack of standardization has made relative comparisons between results from different laboratories or test programs difficult and sometimes impossible. Information regarding instrumentation location, orientation, and pre and post processing of the data is often insufficient to reconstruct the 3D time history of occupant response to a specific acceleration input. The development of sophisticated and complex escape systems and crashworthy seating require a reliable, repeatable and fully instrumented standard manikin that will accurately interact with the escape or protective system to produce realistic/seat occupant response enabling accurate assessment of system performance and associated injury potentials. The manikin must provide the biofidelity of its human counterpart, while concurrently supporting the instrumentation and electronics necessary to measure and record the dynamic response, making direct comparison between manikin data and known response possible.

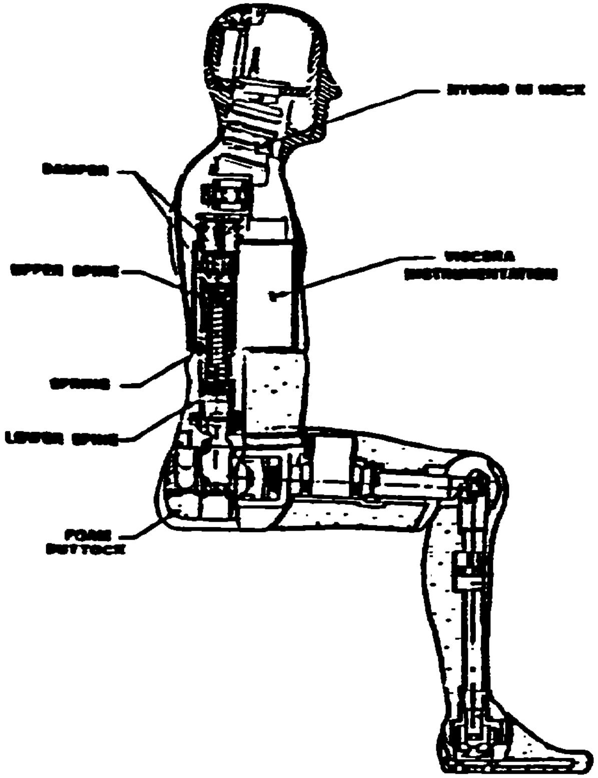
1.1 Historical Manikin Development

The earliest recorded testing involving an anthropomorphic dummy was conducted by Start and Roth (1944) of the Dornier Werke in the development and testing of an ejection seat for the D0335 aircraft. This dummy was a simple wooden form used primarily for ballasting the seat with representative body weights. The best known early design is probably the rugged ejection seat dummy built by Sierra Engineering Company for the Air Force about 1949. Although it had limited articulation and poor biomechanical fidelity, it filled an important need in the industry as a human simulator. In 1954, Alderson Research Laboratories, Inc., created the first mass production dummy which was unique because of its modular design. This technique permitted new parts to be added as needs and know-how changed over the next decade. In 1967, both major dummy manufacturers marketed new devices which featured increased articulation in the vertebral column and shoulders plus increased compliance in the thorax. These were' worthwhile changes even though, on an overall basis, the fidelity of duplicating human impact response was still limited. In 1968, the SAE Recommended Practice J963 was published as a partial definition of a 50th percentile anthropomorphic test device. Although deficient in many respects, it was a first step in specifying many of the items which are required to achieve standardization. Alderson upgraded their designs to meet J963 in 1968 and 1971, while the Sierra counterpart appeared in 1970.

Todays most commonly utilized GARD dummies, typically employed for escape system testing, serve more as an instrumentation platform than a test article to quantify seat-occupant interaction. For dynamic tests, they provide a convenient structure to mount instrumentation and telemetry packages, provide ballast to alter seat acceleration profiles, and are used to represent typical anatomical segment cross sections subjected to windblast and detection of deficiencies in clearance enveloped provided.

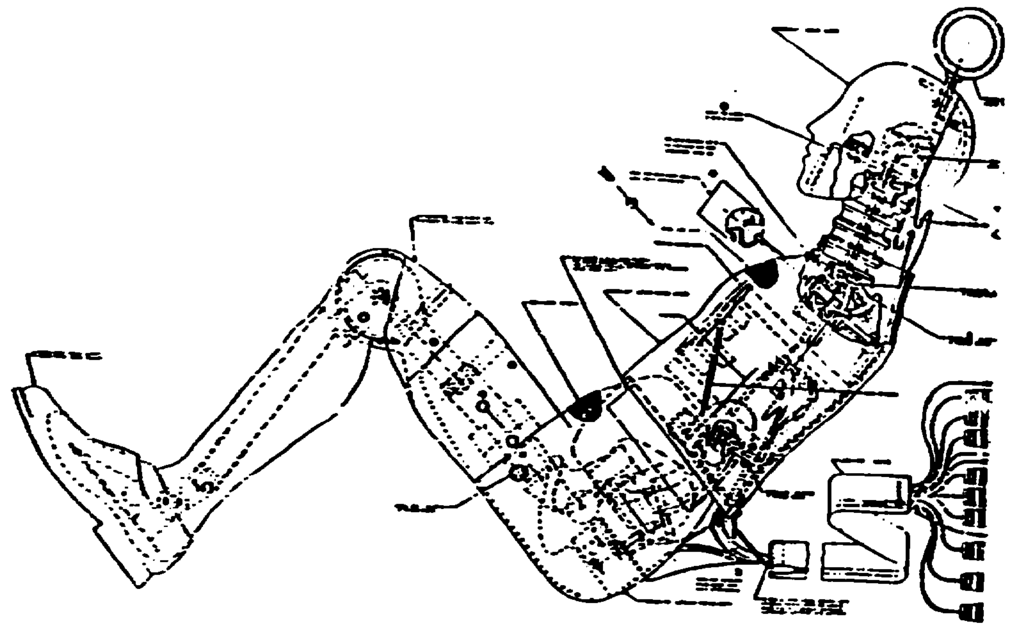
The advanced manikin forms of today (Hybrid III type manikin and the ADAM) represent the state of the art technology in attempting to produce a biofidelic human analogue. The ADAM[1] introduced a flexible spine design, based on the conclusion that having an elastic spine in the vertical direction coupled to the buttock spring assembly, created by the skin/form buttock covering would provide adequate simulation of human response to impulsive loading in the vertical direction. Illustrated in Figure #1 is the ADAM flexible spine, consisting of a linear spring/damper unit (automobile oleo strut), providing damping to impulsive inputs of the upper torso. An upper/lower tube assembly provides the yaw motions of the upper body with respect to the pelvis. Pitch and roll motions of the upper torso with respect to the pelvis are provided by the lumbar articulation mechanisms.

The Hybrid III type manikin illustrated in Figure #2 is a state of the art manikin, with human test data available for comparison and validation of response. The Hybrid III has become a standardized test article utilized at various laboratories with promising results. The Hybrid III is a flexible manikin capable of three dimensional response to an omni directional input, consequently exhibiting a realistic interaction with restraint and



ADAM Cross Section

ADAM
FIGURE 1



HYBRID III
FIGURE 2

seating systems under test. This manikin has been chosen by the Navy to update testing protocols associated with escape and safety equipment.

The development of Hybrid III by General Motors can be traced back to 1971 and its history, objectives and attributes are briefly outlined below.

Hybrid 1 (1971)

- Standardization of parts
- Interchangeability and ease of repair
- Designated Instrumentation location
- Improved test reproducibility
- Head tri-axial instrumentation (head center of gravity)
- Molded rubber neck
- Repeatable and durable but not biomechanically based
- Thorax tri-axial instrumentation (at center of gravity)
- More anatomically correct pelvis
- Femur load measurement (standardized load cell)
- Improved knee flesh covering

Hybrid II (1972)

- Improved repeatability combined with durability and serviceability
- Redesigned skull to eliminate mechanical resonance
- Improved head-neck interface
- Rubber neck retained with redesigned neck mount
- Improved thoracic structure
- Self centering shoulders with a better distribution of load in the shoulder region
- Incorporated butyl rubber lumbar spine

Part 572 Dummy

The Part 572 dummy is a Hybrid II dummy developed as a repeatable lap/shoulder harness test device and was used for limited qualification testing of air-bag restraint systems. It is a 50th percentile adult male dummy specified in the Code of Federal Regulations to be used for compliance testing of passive restraint systems.

ATD 502 (1973)

- Incorporated biomechanically based geometry, moment of inertia and hard surface impact response
- Polyacrylate neck with improved damping characteristics
- Adjustable neck mount (pitch)
- Thoracic structure (similar to Hybrid II) redesigned in the shoulder to improve belt-to-shoulder interface.
- Constant torque shoulder and knee joints
- Polyacrylate lumbar spine

Deficiencies in the aforementioned dummies are as follows:

- Lack of biomechanical response

  Neck, Thorax, Knees

- Lack of measurement of biomechanical parameters

  Neck axial and shear loads
  Moments about the occipital condyles
  Sternal to thoracic spine displacement

Hybrid III (1975)

- Serviceability, durability and setup stability improved over Hybrid II and ATD 402 dummies.

- Measurable improvement in component biofidelity.

- Significant improvement over ATD 502 in following areas:

  New Neck
  Redesigned thorax
  Redistributed lower torso weight

1.2 Hybrid III Description

In addition to the structural modifications indicated, instrumentation capabilities were expanded over those existing in the ATD 502. Transducers were incorporated in the Hybrid III design to measure orthogonal linear acceleration components of the head, chest, the sagittal plane reactions (axial and shear forces and bending moment) between the head and the neck at the occipital condyles, the displacement of the sternum relative to the thoracic spine, and the axial femoral shaft loads.

The Hybrid III head consists of an aluminum shell covered by constant thickness vinyl skin over the cranium, incorporating a tri-axial accelerometer package located at the center of gravity. The neck exhibits one piece biomechanical bending and damping response in flexion and extension. Three rigid aluminum vertebral elements are molded in butyl elastometer, providing the high damping characteristics. Aluminum end plates attach the segment to the head and thorax, with a steel cable running through the center of the neck. Special transducers to measure axial and shear loads and moment about the occipital condyles have been developed. The thorax of Hybrid III is similar to both Hybrid II and ATD 502. It consists of 6 ribs, connected to a welded steel spine. The whole assembly is ballasted for correct weight and center of gravity location. The spine provides for attachment of the neck, clavicles, ribs and lumbar spine. A tri-axial accelerometer package also located at the center of gravity. along with a rotary potentiometer to measure chest deflection accommodating upto 90 mm of deflection.

The lumbar spine is a curved polyacrylate elastometer with molded endplates for attachment to the thorax and pelvis. Two steel cables run through the central section. The lower body had correct weight distribution and is ordinarily cast in a seated position. The hip joint is a working joint, but the gluteal and abdominal cast would have to be modified to allow for leg extension. A detailed description of the Hybrid III can be found in Foster (1977).[2]

1.3 DASS: Hybrid III Integrated Data Acquisition and Storage System

Applied Physics Inc. has developed a documented[3,4,5] expertise in the design, development of data acquisition systems for manikin applications. A feasibility prototype data acquisition and storage system was designed, developed and tested; compatible with the instrumentation requirements as defined by the Naval Air Development Center. The system tested the required high sampling frequencies and system throughput rates defining the data storage requirements in terms of memory and execution speed. The microprocessor based system supported 32 signal conditioned signals, sampled at 2000 Hz for 6.6 seconds. The system resolution was based on tri-service requirements. The system configuration supported signal conditioning (variable gain, tunable filter and S/H), A/D conversion, and storage. Additional RS232 communication was provided to download data post experiment to a supporting IBM PC. The prototype was designed to demonstrate system feasibility, performance reliability under the environmental conditions outlined. The system performed successful upto 36 G's, 1800 G/sec onset as tested on the horizontal accelerator at NADC.

This effort was followed by the development of a fully manikin integrated system. The system was retrofit into a modified Hybrid III type manikin, housing all electronic components within the chest cavity. The system was designed to handle 96 channels, typically sampled at 2000 Hz (maximum of 10 KHz), and covering experimental times of upto 12 seconds. As before, the system was structurally and functionally tested at the NADC upto 40 G's with onsets upto 1800 G/sec. The system was based on a 68000 microprocessor housing 4 Mbytes of RAM memory, 96 channels of hybridized signal conditioning, (developed by Applied Physics), and high speed 12 bit A/D conversion. Additionally, the system integrated with a battery subsystem providing all system power and a MMP 600 PCM telemetry system. As before, the system interfaced (via RS232 and high speed GPIB link) to supporting IBM PC, providing an offload media for data recovery and processing.

This development effort successfully demonstrated the capability to fabricate a fully instrumented standalone manikin prototype functioning as a standardized test platform. However, due to the retrofit nature, and the extensive NiCad battery assembly (specified by the Navy) significant weight was added to the manikin. Additionally, the mounting of the data acquisition system within the chest cavity significantly limited chest deformation capabilities, and altered the biodynamic characteristics of the manikin.

2.0 Phase I Analysis/Phase II Recommendations

2.1 Objectives

The objectives of this contractual effort focus on the design, development and fabrication of an enhanced manikin, providing a high degree of biofidelity and a biodynamic response, simulating that of its human counterpart. The manikin will internally provide all transducer/sensors, data acquisition and storage electronics and power to enable the measure, recording and reconstruction of the six degree of freedom response of key anatomically correlatable points to the environments of interest. The design objectives are to provide modularity in design, low maintenance, structural integrity and a repeatable dynamic response.

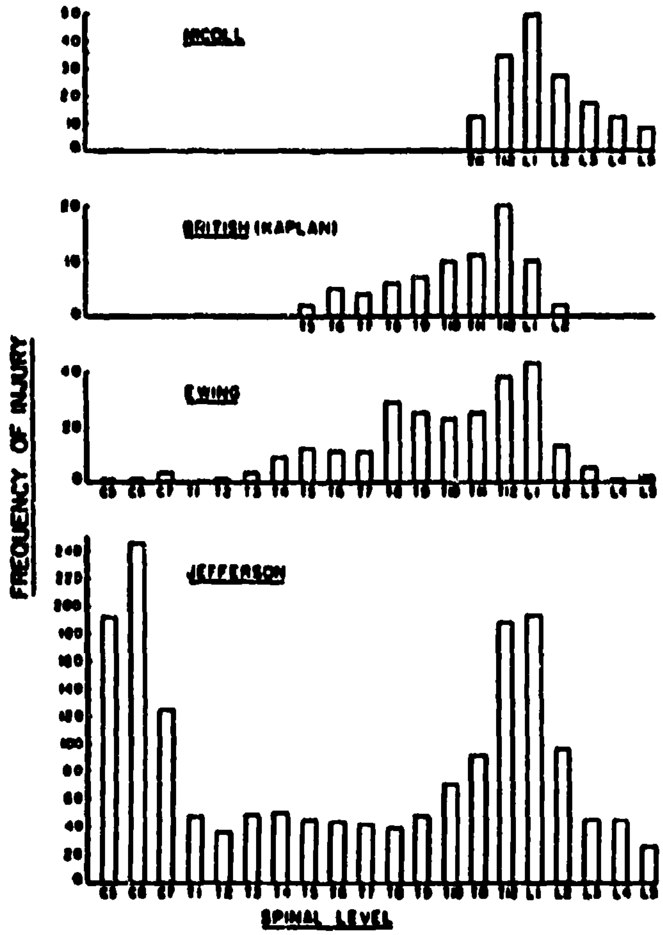
2.1.2 Dynamic Response Objectives

In order to adequately simulate human response and interaction with aircraft escape and protective subsystems, the manikin must adhere to key anthropometric measures and specifications, along with the inertial properties, articulation and segmentation of the human. The manikin articulation must be in sufficient degrees of freedom to simulate response at correlatable anatomical points of interest. These points can be closely related to the areas of injury typically associated with emergency egress and crash/impact events. The primary areas of interest focus on the injuries observed at the head, neck and spine.

One database for injury identification, are operational statistics, defining injuries resulting from various aircraft and ejection accidents. A recent and comprehensive review of acceleration related injuries (1972-1980) in the helicopter environment is that by Shanahan[6] (as reported by Coltman in 1986). the injuries focussed on spinal fractures with the distribution primarily in the T11 to L4 region with the highest incidence, by far, occurring at L1. Naval ejection seat related injuries (1969-1979), as reported by Guill[7] (1981), focus on spinal injuries concentrated in the T6-L1 region, with principal modes at T7-T8 and L1. Cervical injuries concentrated at C2, were also evident, attributed primarily to parachute opening shock, canopy penetration, parachute riser entanglement and aerodynamic lift created by the helmeted head during high air speed ejections. Further injury statistics have been reviewed by many researchers, as summarized by Kazarian,[8] where the distribution of spinal injuries are illustrated by comparing the injury statistics of Kaplan, Nicoll, Ewing, Jefferson, shown in Figure 3. Nicoll's and Jefferson's data indicate the distribution of spinal fractures arising from clinical statistics and Kaplan's from US Army injury statistics. Clearly, the statistics reveal the thorcolumbar spine as the region most susceptible to injury.

2.2 Manikin

It is proposed that the enhanced manikin form resulting from this development effort be based on the existing Hybrid III type manikin. Applied Physics has extensive experience in the mechanical structure of this manikin and has developed many components to retrofit the manikin



Distribution and frequency of spinal trauma from clinical and operational statistics

INJURY STATISTICS
FIGURE 3

enhancing capabilities and performance. The ADAM manikin represents a complex non-modular design, where all components (i.e., Data Acquisition System, batteries, etc.) are integral parts o: the manikin, making modification difficult and costly. Due to its basic integrated architecture, the ADAM represents a significant cost, beyond the of the Hybrid III.

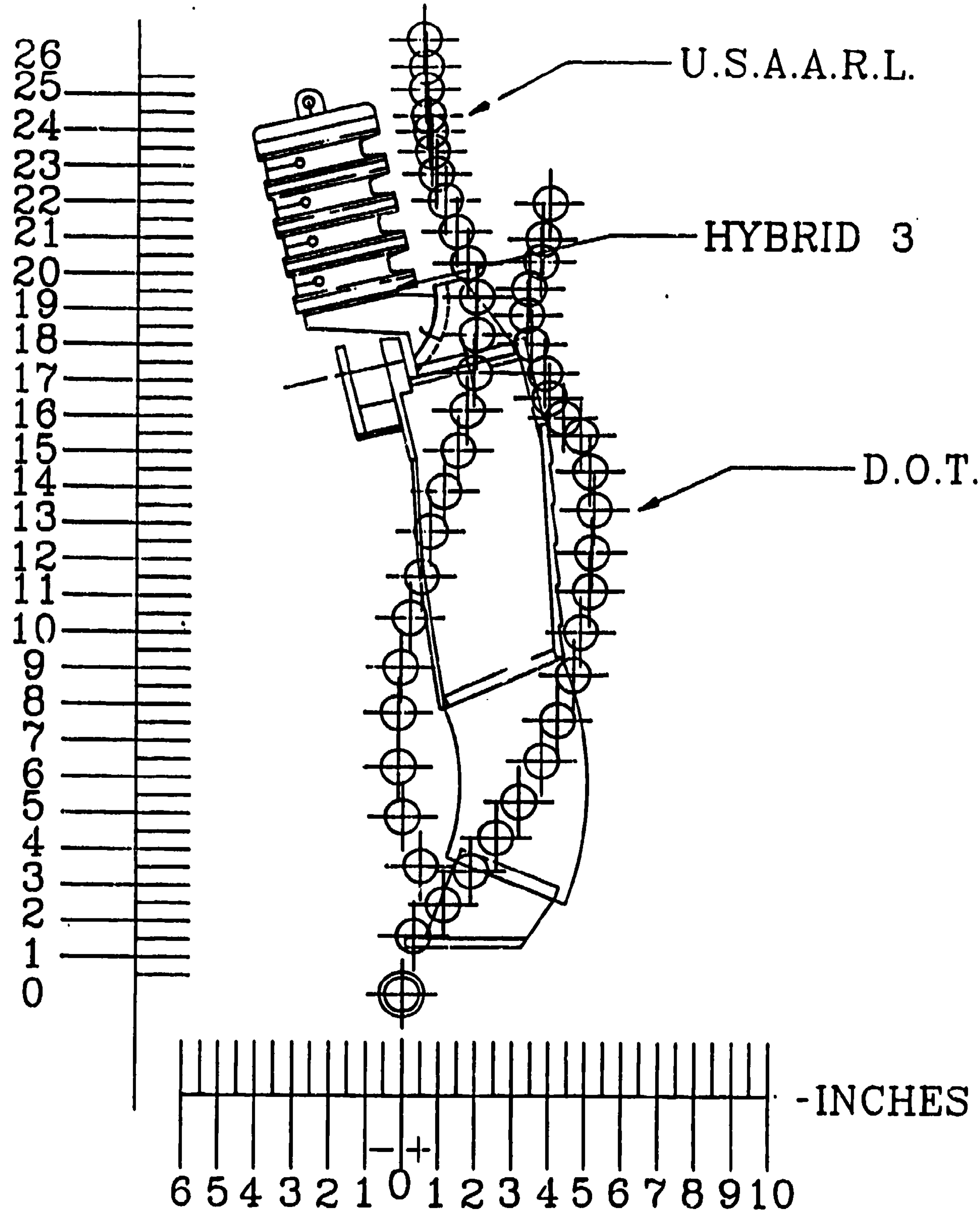
The basic Hybrid III will be purchased from First Technology Safety Systems, based on a 50th percentile aviator as defined in the Tri-service specification.[9] The manikin will integrate with a DOT part 572 head, and Hybrid III neck, to provide an improved compliance with helmet testing requirements. The manikin will be delivered with the upright posture lumbar spine, as opposed to the "slumped-lumbar" spine, however, the spine will be retrofit with the design proposed in this report. The manikin skin will be molded in a seated configuration, however, the option to support a removeable and interchangeable skin contour varying the skin contour from seated to standing is desirable and will be further investigated in Phase II. The manikin legs will provide full extension, as allowable by the pelvic skin to conform with parachute testing modes.

2.3 Flexible Spine

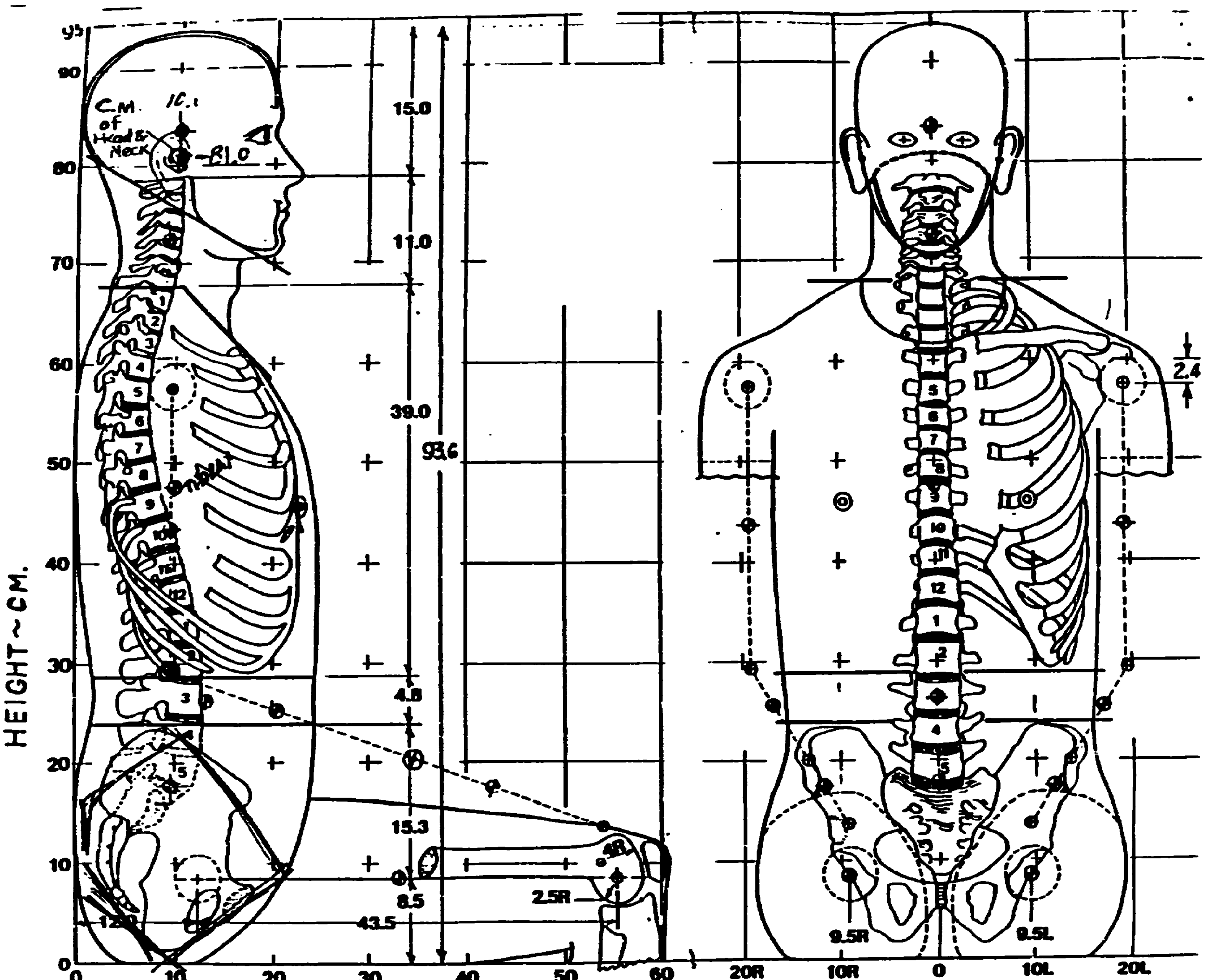
Clearly, the injury statistics analyzed indicated the thorocolumbar spine as the region most susceptible to injury. It is proposed that to better stimulate human spinal response and dynamics, a flexible spine, highly articulated and compatible with the existing Hybrid II head, Hybrid III neck, shoulder and pelvic assemblies be developed and integrated into the manikin.

Review of the human spine configuration and dynamics indicated several key parameters to be considered. First, the initial position of the spine or contour varies as a function of standing position, seated position and seat geometry. Secondly, the spine exhibits a non-linear response when exposed to an acceleration profile. Finally, spinal compression varies as a function of vertebra and loading. Since these response characteristics are not uniformly distributed throughout the spine, key anatomical locations were identified with simulating mechanical design features incorporated at these locations.

Review of spinal initial position can be summarized in Figure #4. Indicated is the extensive variation of spinal contour, as function of seat geometry. The tri-service representation illustrated in Figure #5, is based on 90° full upright seating. In contrast, the DOT[10] representation, illustrated in Figure #6, focuses on spinal contour conforming to a hardseat arrangement simulating commercial automobile seating. Clearly, a portion of the varying spinal contour is attained by a variation of the pelvis orientation, relative to the seat base. However, it is unlikely that a mechanically equivalent pelvis enclosed is a premolded polymer skin will enable that degree of pelvis rotation. Indicated is the need to provide several adjustment locations within the spine to enable modification of the contour. Additionally, due to limited pelvis rotation, an increased adjustment capability will be required at approximately the L5 or start of the lumbar spine position.

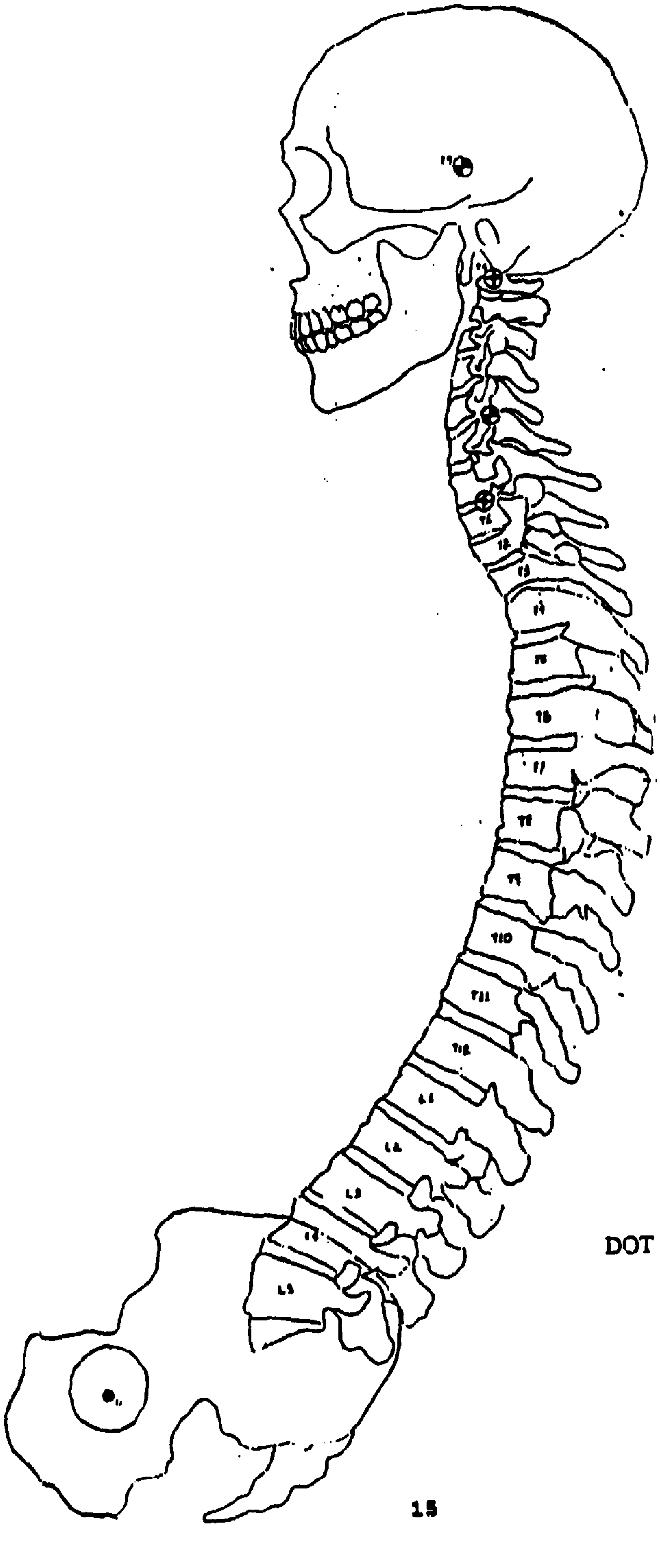


SPINAL INITIAL POSITION
FIGURE 4



UPRIGHT SEATING CONFIGURATION

FIGURE 5



DOT SEATING CONFIGURATION
FIGURE 6

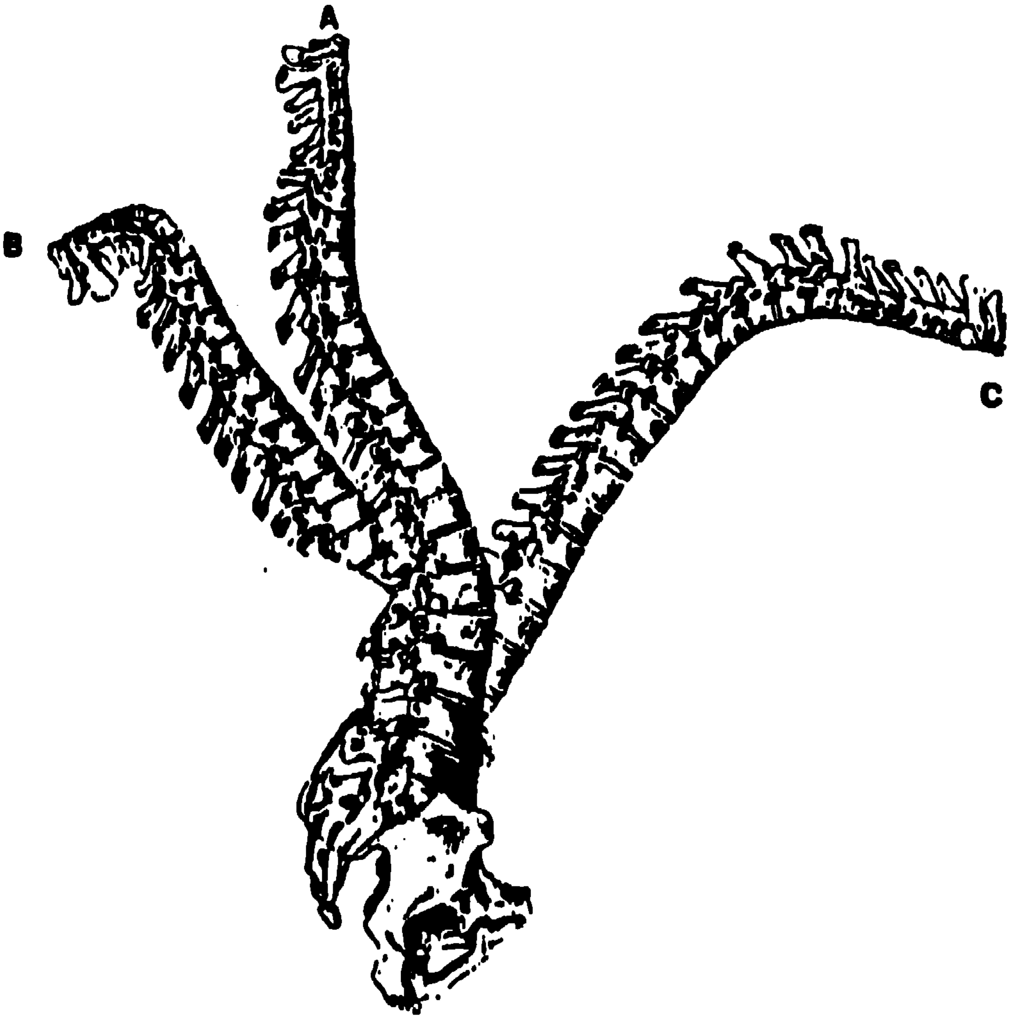
In an attempt to address the non-linearity of spinal response, a typical midsagital plane response envelope, as illustrated in Figure #7, was analyzed. This typical response was extracted from the ADAM RFP,[11] digitized and scaled to a 50th percentile geometry, based on overall spine length as defined by the tri-service specification. The seated initial position defined as normal, closely correlates to the position defined as tri-service in Figure #4. The non-uniform spinal bending is observed in both flexion and extension defining the areas requiring increased bending capability. These areas are indicated as "A" and "B" in the flexion and extension profiles, respectively. Work done by Privitzer[12] and Belytschko, simulating the dynamic response of the spine under Gz loading as a function of time as illustrated in Figure #8. Indicated is a spinal compression and change in contour as a function of load and load duration.

Various specified response characteristics have been detailed within the AATD,[13] defining both head rotations relative to the torso as a function of movement about the head-neck junction, and the response of the thoracolumbar spine, as a function of moment of applied force about the H-point axis. However, as detailed as these profiles are, they provide limited design input and act more as test envelope in which to demonstrate the end product manikin response. The data does indicate the requirement to enable calibration or adjustment of the mechanical spine modifying the response characteristic.

2.3.1 Mechanical Configuration

Due to the limited dynamic response characteristics of the Hybrid III spine, and consequent inability to accurately simulate human response, it is recommended that a flexible spine be developed and integrated into the proposed enhanced manikin. The proposed design is based on a mechanical vertebra structure, simulating the dynamics of interest and providing the instrumentation to measure the loads, moments and acceleration at key anatomically representative points. The spine will provide adjustment capabilities to alter the initial position or contour of the spine, and preload or calibrate the spine to alter the dynamic response (flexion, extension, bending and compression).

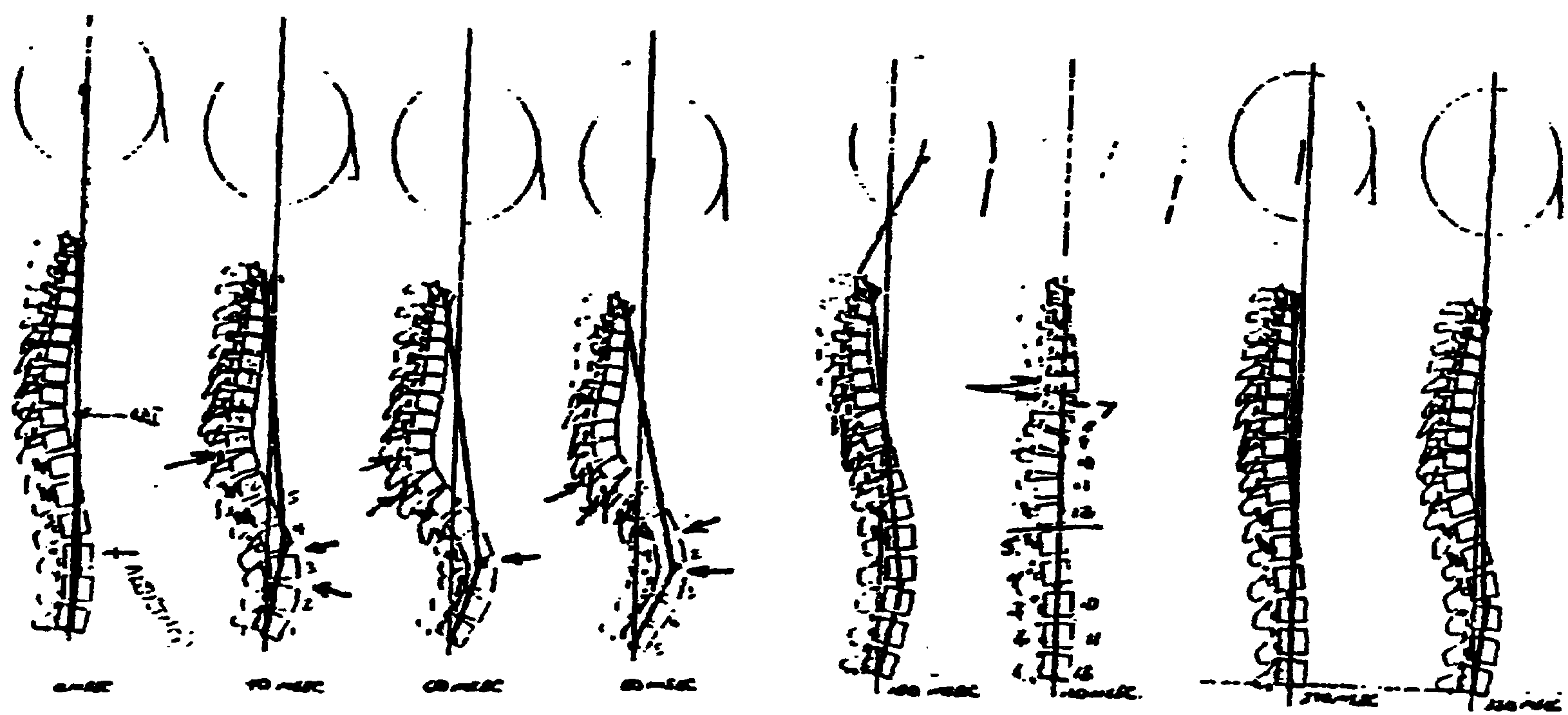
Illustrated in Figures #9A and 9B are variations of the proposed flexible spine, consisting of multiple vertebra, adjustment blocks, load cells, mountings for the head and shoulder assemblies, and an alternative or support rigid segment. The spine supports a modular design, subdivided into three distinct sections, corresponding to a lumbar region, thoracic region and neck. Each region or section supports a dedicated central cable assembly providing independent adjustment or calibration over each region. The cables can individually be adjusted to modify or alter spine response to conform with the envelopes detailed in the AATD. As illustrated, the spine interfaces or mounts to the pelvis via a Denton load cell, located at the anatomic L5 position as defined relative to the hip position (H point). The spine as shown in both figures consists of several modular components stacked to satisfy the response and adjustment characteristics. One such component is the mechanical vertebra illustrated in Figure #10. Each mechanical vertebra consists of a 3 inch diameter, 86 durometer rubber



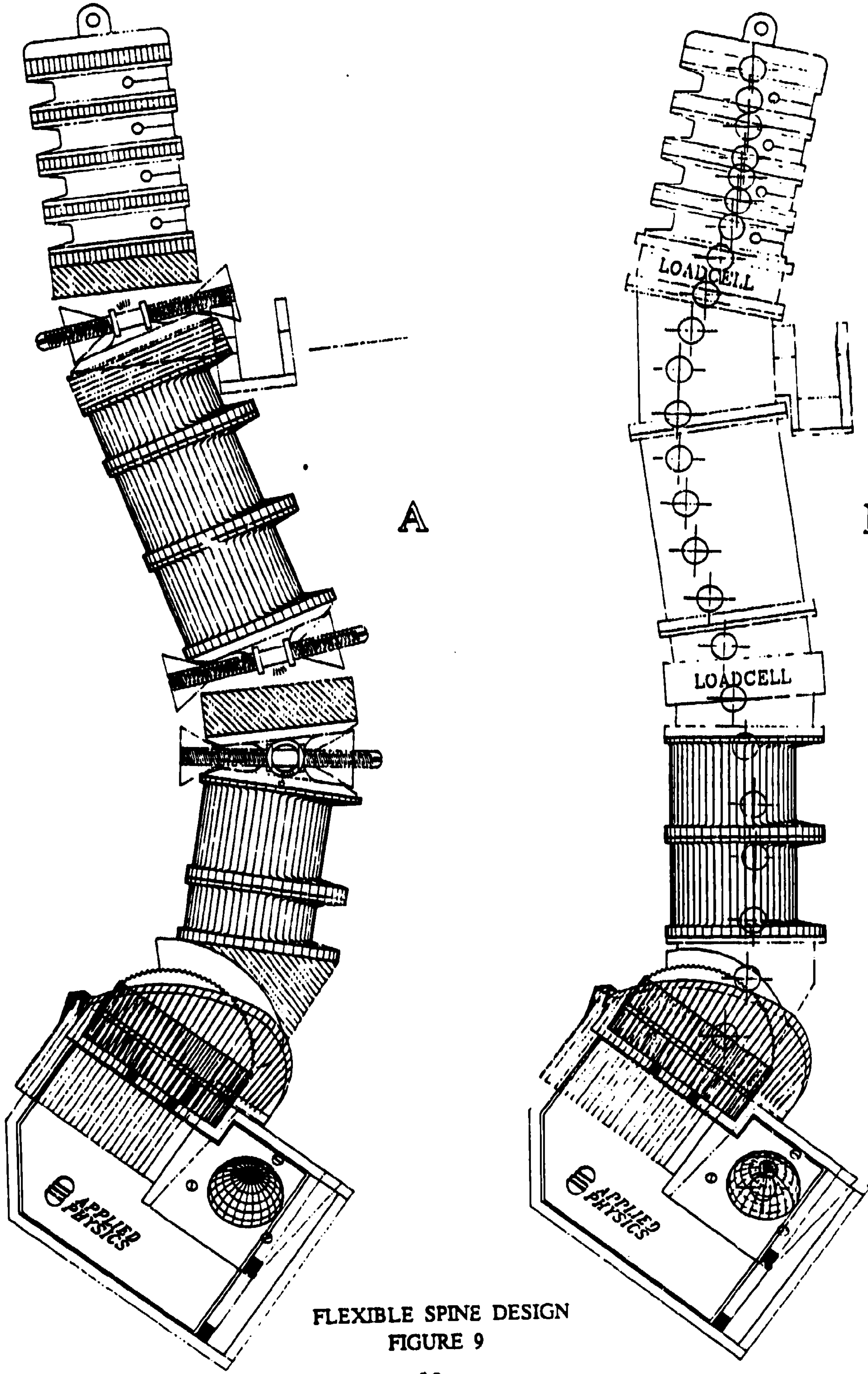
Spinal mid-sagittal plane excursions
(standing position) :

A. normal
B. extension
C. flexion

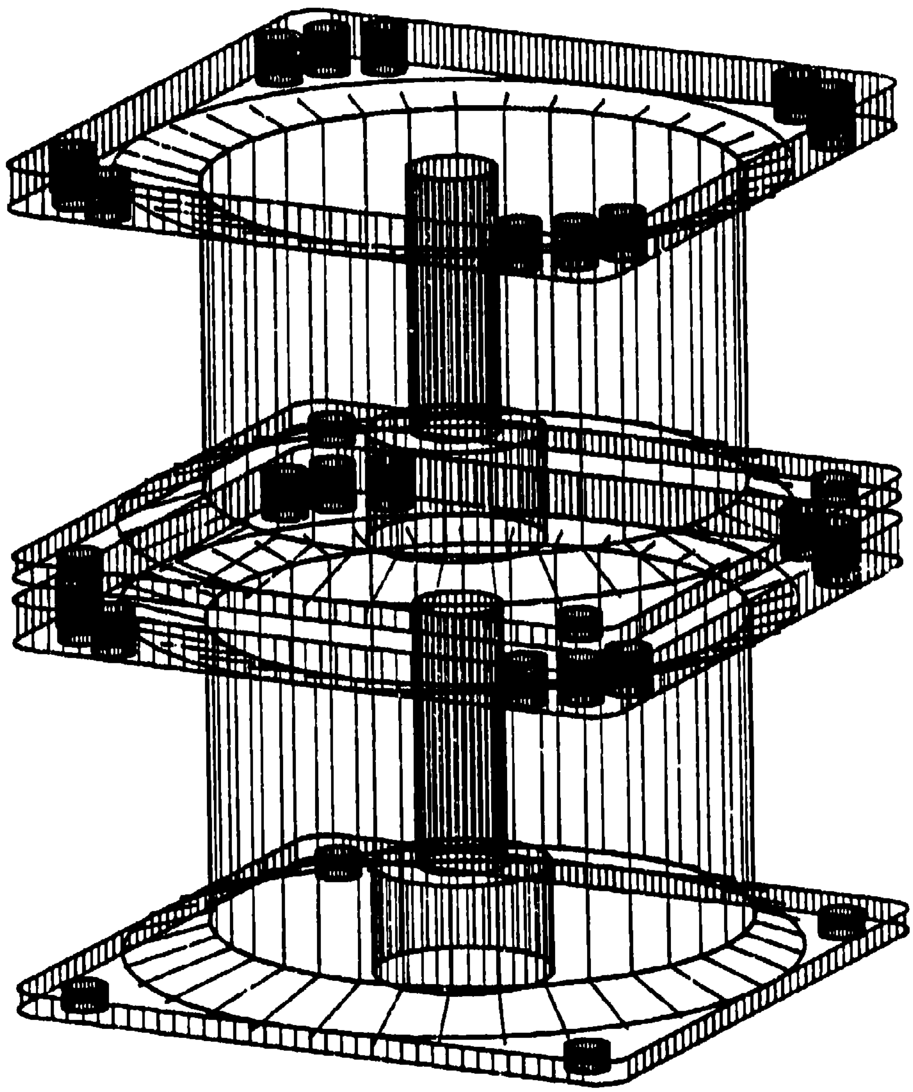
MIDSAGITAL RESPONSE
FIGURE 7



SPINAL COMPRESSION 10 Gz RESPONSE
FIGURE 8



FLEXIBLE SPINE DESIGN
FIGURE 9

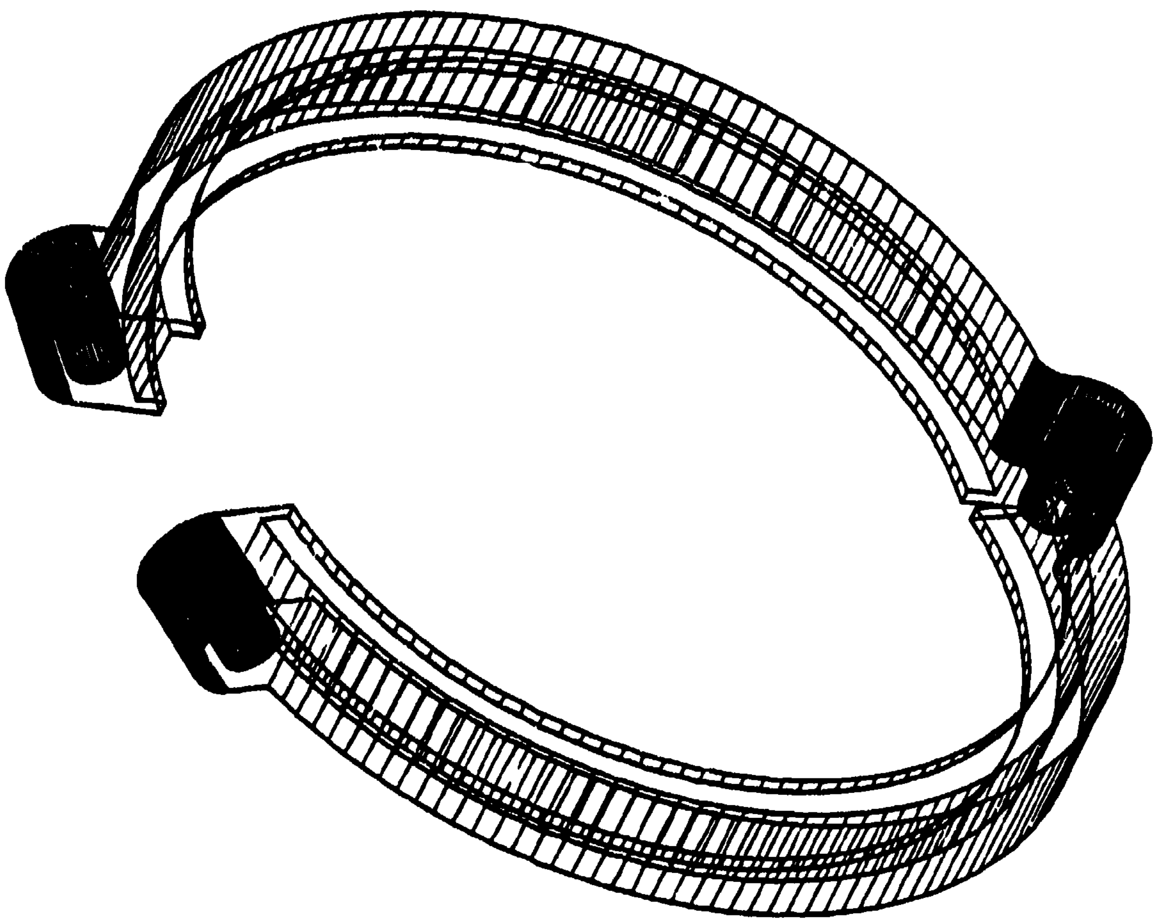


MECHANICAL VERTEBRA
FIGURE 10

cylinders, adhered to aluminum top and bottom mounting plates. These vertebra will be available in 2" and 1" heights as required. These vertebra will provide the bending and compression characteristics as outlined. Hyper extension and flexion will be accomplished in a similar manner to that of the Hybrid III neck by slotting certain vertebra at the anatomic locations indicated. A second component of the proposed spine are the adjustment blocks, enable the initial position of the spine to be adjusted to conform to varying seat geometries. Two such adjustment assemblies are illustrated. In Figure #9A, a screw type mechanism is illustrated enabling a continuous spinal adjustment over 11 degrees. The basic problem of such a design is the lack of repeatability in adjusting the spine to exactly the same position for each test. As a preferred alternative, adjustment wedges as illustrated in Figure #9B, will be fabricated to enable fixed adjustments to be made on the spine contour. Several wedge sets will be provided to enable initial position adjustments. These wedges will be horseshoe shaped and provide a hallowed central area to enable access and adjustment of the central cables. The final component of the spine are the load cells providing key force and moment information. The load cells will be based on the Denton C1709, having mounting plates incorporated for inclusion at T1 and T12. These modular components will be held together by the internal cable and a strap assembly as illustrated in Figure #11. The strap assembly provides an easy means of disassembling and restructuring the spine. Alternatively, each component of the spine can be bolted together. Finally, as illustrated in Figure #9B, a modular and compatible rigid spine segment will be constructed to substitute for the three thoracic vertebra, providing an alternative configuration.

The lumbar region of the spine consists of an L5/L4 adjustment assembly, providing approximately 30 degrees of spinal adjustment relative to the pelvis. This bracket will enable a wide range of adjustment to compensate for the typical pelvis rotations outlined. Coupled to the L4/L5 adjustment assembly are three mechanical vertebra providing the compressive, bending and rotational characteristics of the lumbar spine. To provide the non-uniform bending at sections such as L3/L2; T12/T11; T1/T2 as indicated in the responses illustrated in Figures #7 and 8, the rubber vertebra will be slotted similar to that shown on the Hybrid III neck. The exact slot locations and depths will be determined during phase II prototyping. The thoracic region of the spine provides a load cell mounting at approximately the L1/T12 position. On either side of the load cell, an initial position mounting wedge. The load cell at the T1 position, represents the upper portion of the thoracic spine. As before, an adjustment wedge assembly provides initial position adjustment of the neck relative to the thorax and adjustment of the central cable of the thorax. Coupled to the wedge assembly is a shoulder mounting assembly interfacing the flexible spine to the existing Hybrid III shoulder mechanism. The shoulder assembly is approximately located at T4, corresponding to the existing Hybrid III position. Between the T1-T12 load cells and adjustment wedges are three vertebra as previously described. As an option, the three vertebra can be substituted by a rigid spine segment as illustrated in Figure #9B. The spine will support the existing Hybrid III head, modified to interface with the Hybrid II head.

The spine as illustrated provides a modular, stackable, multi-segment spine, providing easy access for cable adjustment, initial position adjustment and disassembly. It is recommended that the spine be disassembled at a



STRAP MECHANISM
FIGURE 11

minimum of four locations corresponding to approximately C1/C2, T1, T10-T12 and L5. Load cell will be provided at C1-C2, T1, and L5, a mounting block will be provided at approximately T12 for future inclusion of the load.

The current effort recommends the utilization of the existing Hybrid III ribs, mounted to a spring steel assembly, riding along the flexible spine. The details of this assembly will be addressed, under phase II, taking into account the spinal flexibility and motion, along with the required 3 inches of chest deformation.

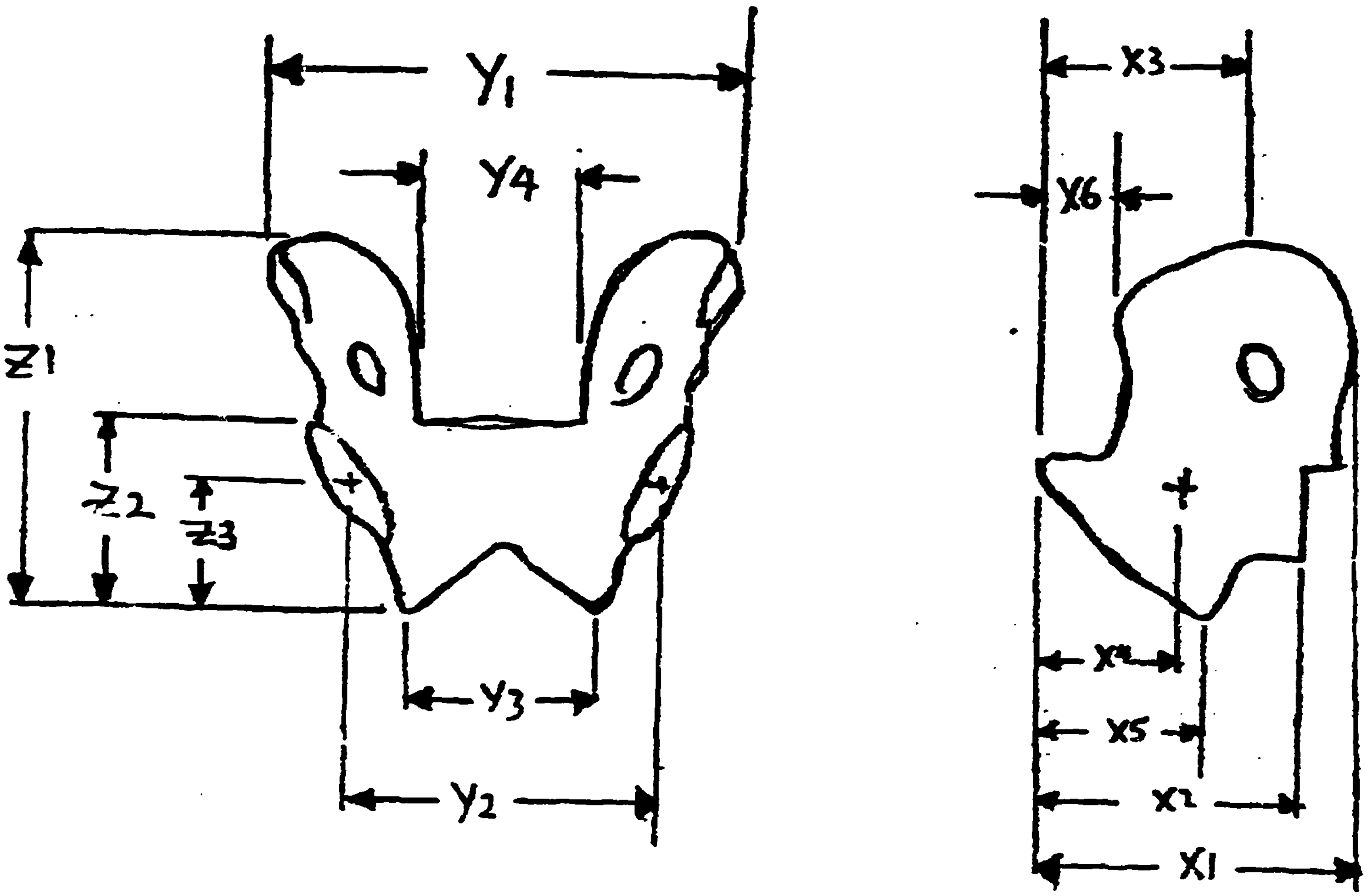
2.4 Pelvis

In order to provide the spinal flexibility and chest deformation characteristics (approximately 3 inches), it is necessary to offload the weight and structure introduced by the inclusion of the data acquisition system into the chest cavity. Analysis of current manikin pelves, such as the Hybrid II and III are both disproportionately heavy, as documented by Reynolds[14] (1982) and Frisch[15] (1987) based on the fraction of total weight and are anthropometrically non-representative of the aviator population. Applied Physics proposes the design of a mechanically equivalent pelvis to the spatical geometry documented, providing both a anthropometrically representative pelvis and a housing or mounting assembly for the electronics proposed. The pelvis design would account for the placement of the load cell at the base of the spine.

The initial analysis focused on the existing pelvis geometry supported by the Hybrid III. The Hybrid III basically supports two pelvis geometries one for the 50th percentile, illustrated in Figure #12, and one for the 5th and 95th percentiles, as illustrated in Figure #13. The detailed dimensions corresponding to each is provided in Table #1, (data provided from First Technology Safety Systems).

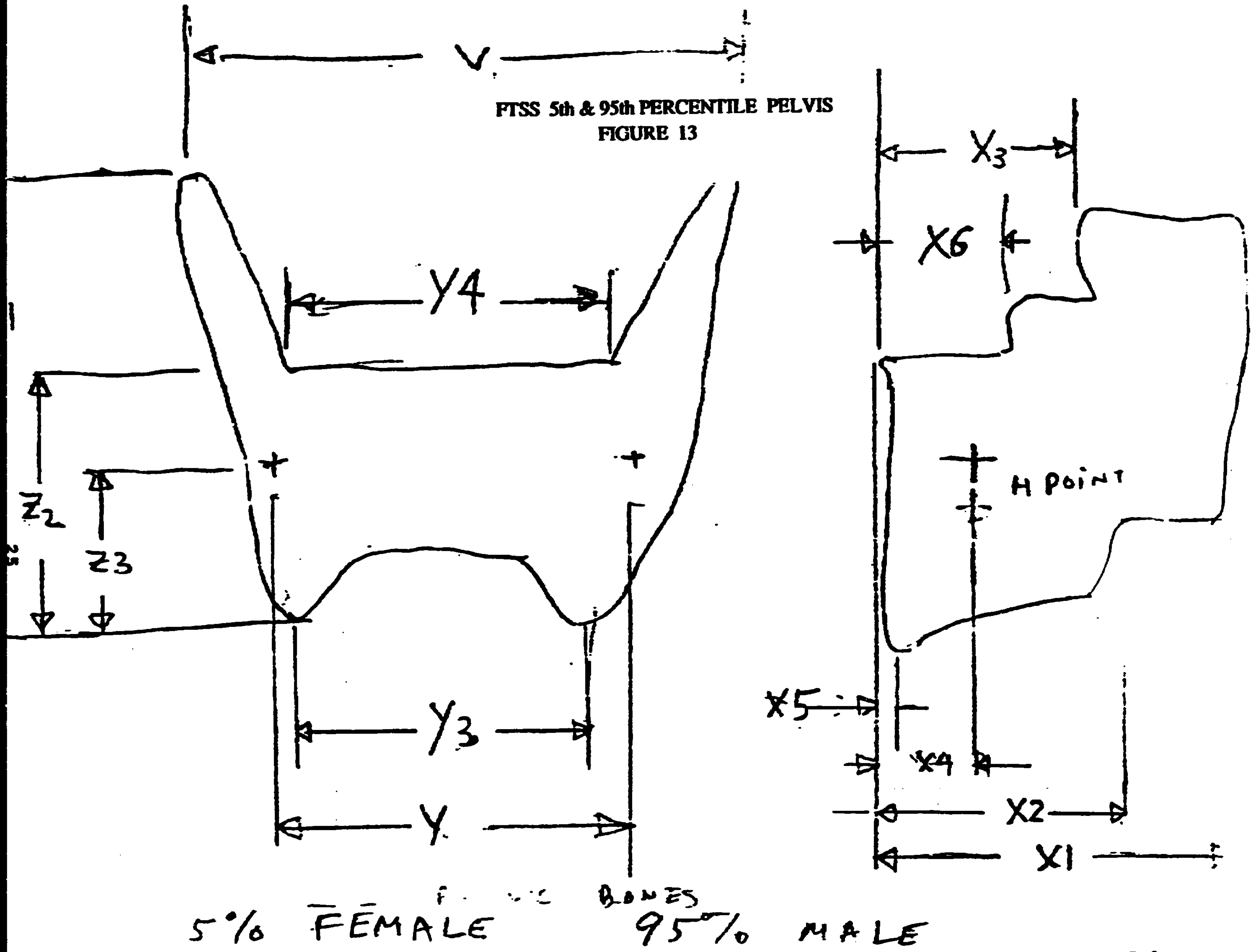
In order to design a new enhanced and anatomically representative pelvis, specific key parameters defining the pelvis geometry had to be determined. The parameters utilized as guidelines to the pelvis geometry are defined as illustrated in Figure #14. Applied Physics studied the geometries developed by Esther Pryor[15] for USAARL, illustrated in Figure #15, the DOT geometry, illustrated in Figure #16 and the Reynolds models developed for the FAA. For each case, the parameters of interest are listed in Table #2. Clearly, there is a close correlation between all the data sets, as one would expect.

Applied Physics recommends the development of a custom pelvis, based on the geometry outlined by Pryor reflecting tri-service anthropometry. The primary function of the pelvis is to provide an anatomically accurate representation of the human pelvis, while simultaneously providing a mounting platform for a portion of the data acquisition and storage electronics. The recommended design is illustrated in Figure #17, consisting of several primary components. The main structure is a welded box like structure, consisting of 3/16 - 5/16 steel plates (top, bottom, 2 sides), providing tl structural integrity necessary for the environments in question. Within this box structure is the analog signal conditioning portion of the data acquisition and storag stem to be described in later sections. The front and back plates (3/16 . num) provide access to the



FTSS 50th PERCENTILE MANIKIN
FIGURE 12

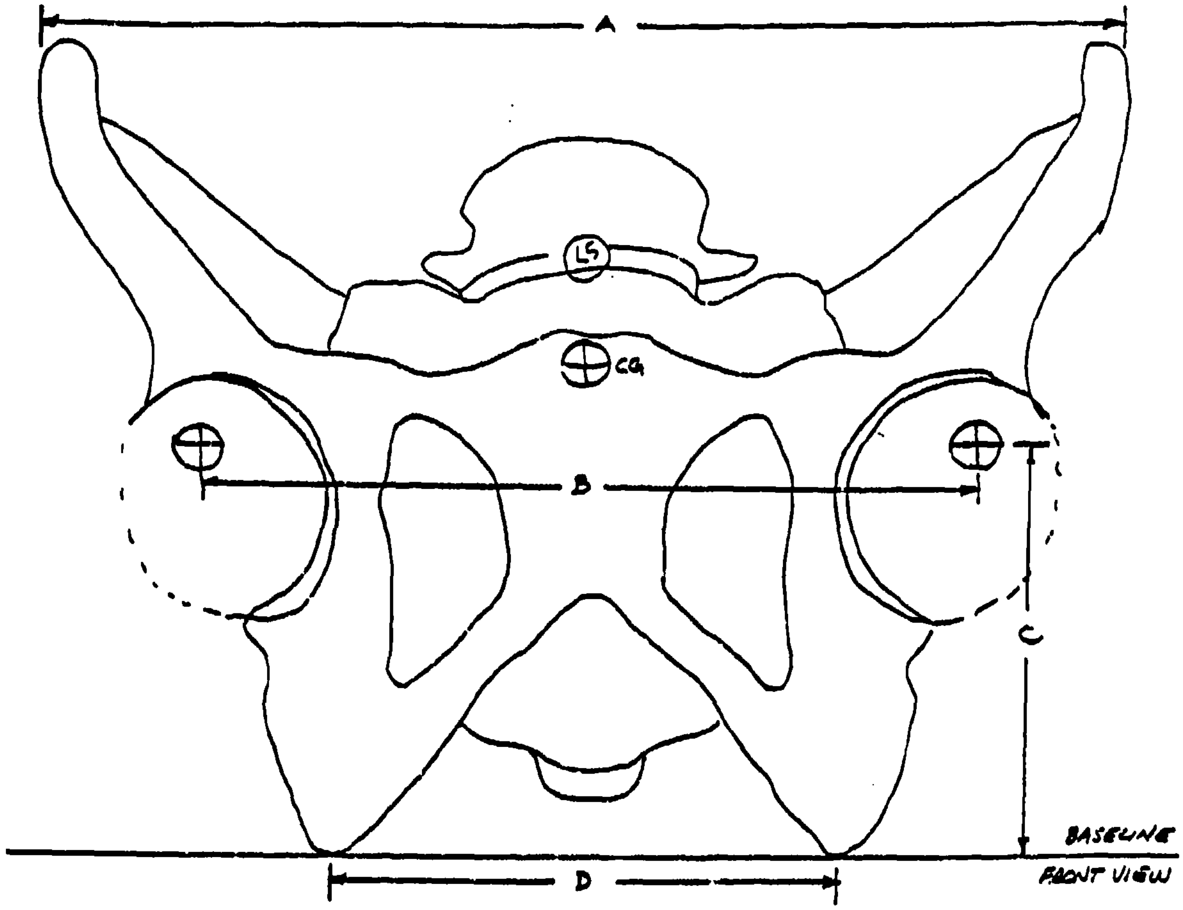
FTSS 5th & 95th PERCENTILE PELVIS
FIGURE 13

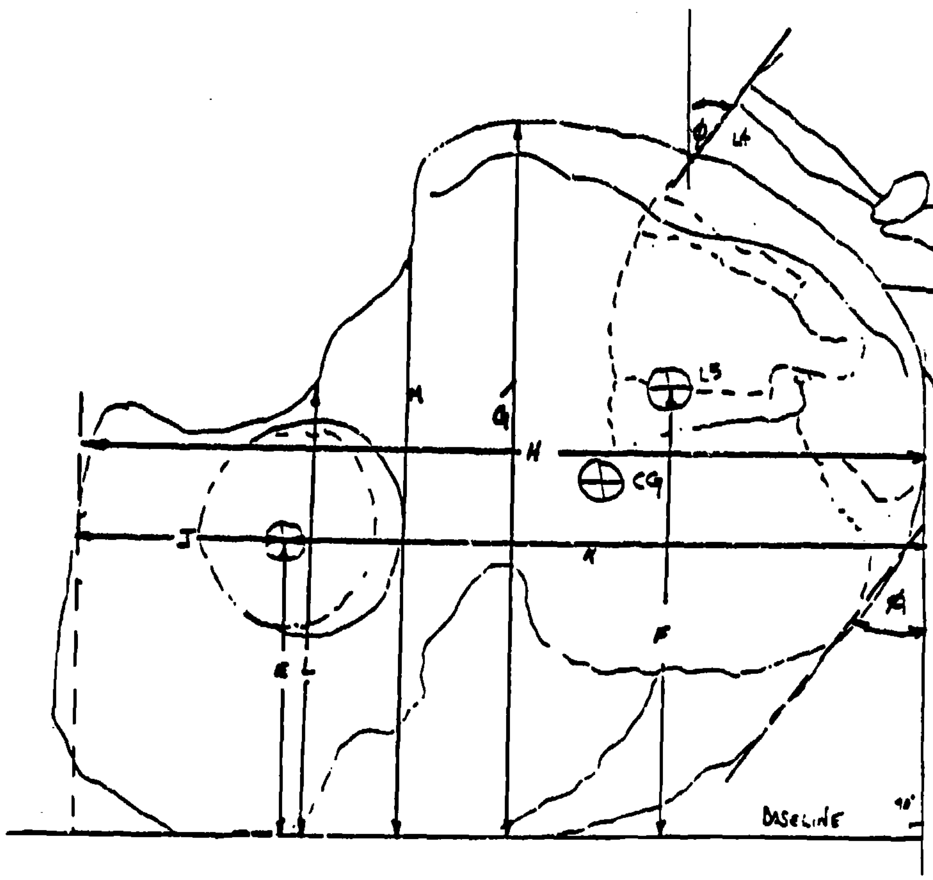


PELVIC BONE DIMENSIONS

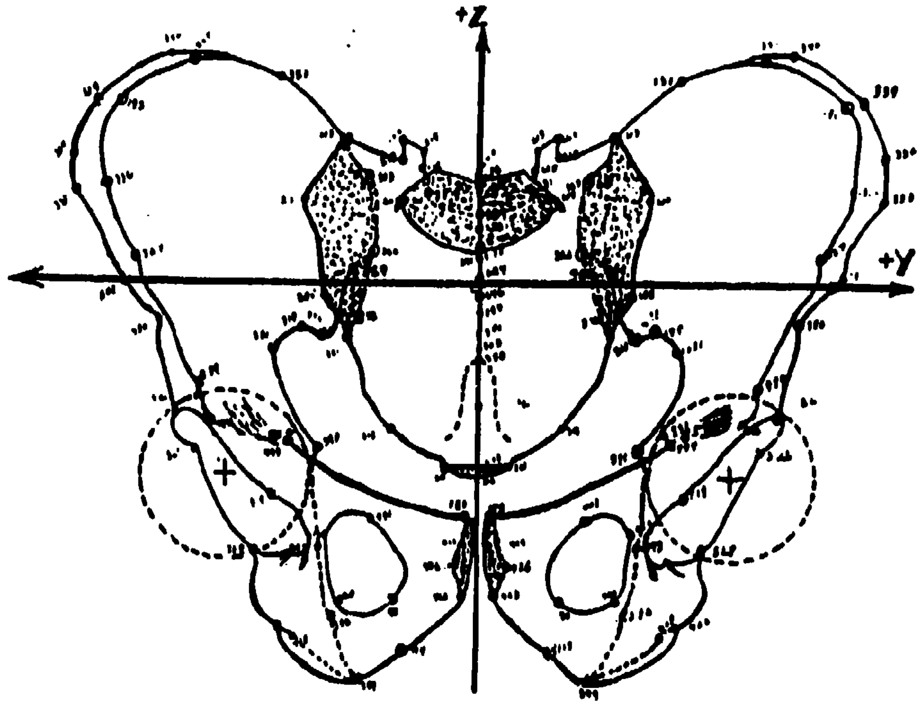
	Hybrid III Type 5th Percentile	Hybrid III 50th Percentile	Hybrid III Type 95th Percentile
Z1	6.03	8.75	6.78
Z2	3.84	4.31	4.16
Z3	2.66	2.99	2.80
Y1	9.80	11.00	10.60
Y2	6.31	6.875	6.00
Y3	4.81	4.19	4.24
Y4	3.94	3.90	7.48
X1	6.50	7.2	7.48
X2	5.75	6.06	6.67
X3	2.20	5.22	2.59
X4	1.88	3.15	1.90
X5	1.68	3.60	1.04
X6	1.81	1.94	2.15

HYBRID III PELVIS GEOMETRY
TABLE 1

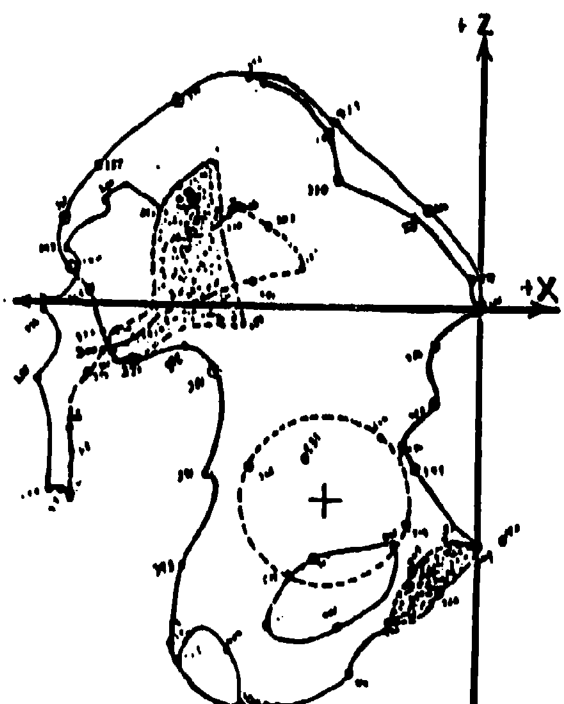




GENERAL PELVIS GEOMETRY
FIGURE 14

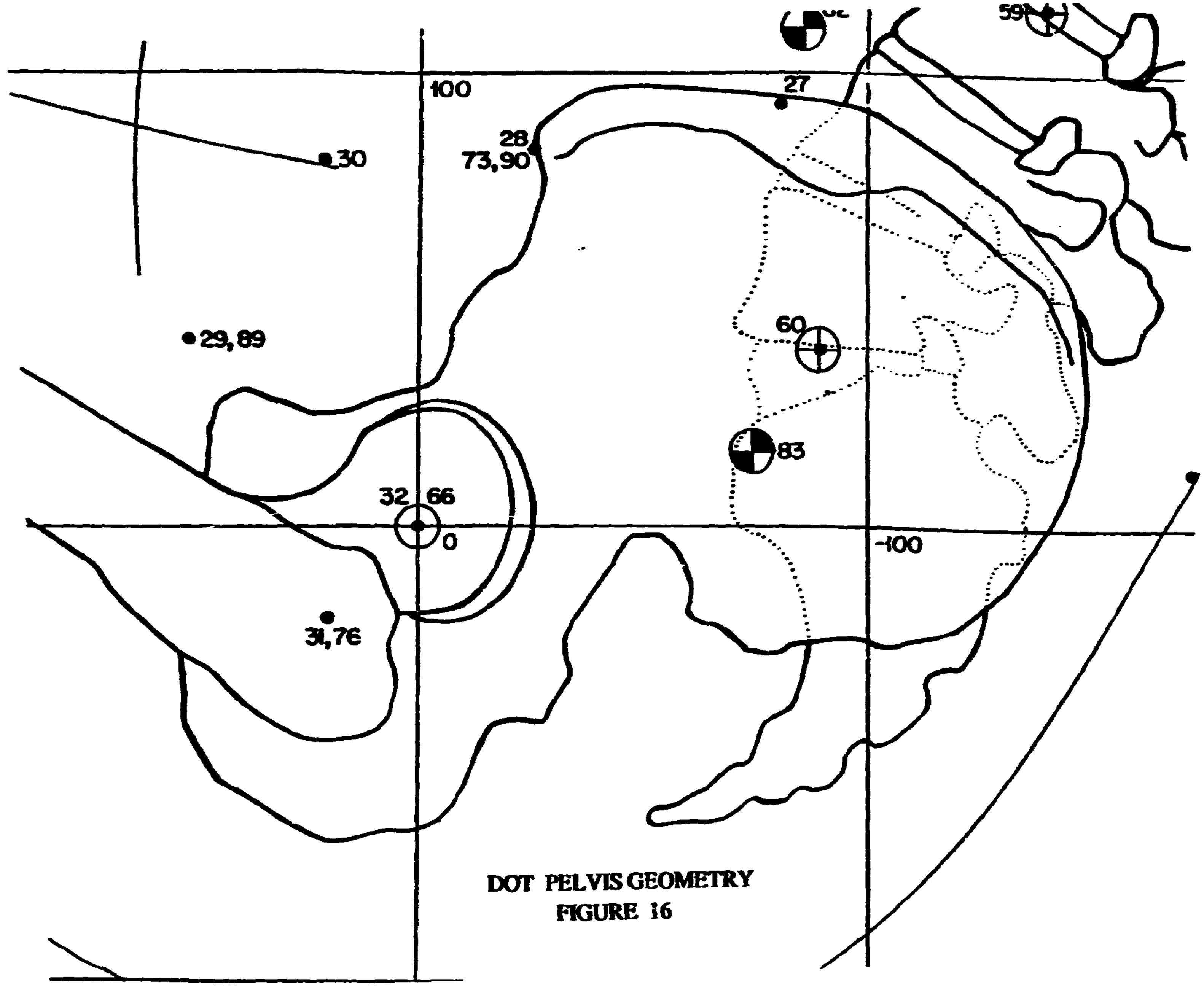


FRONT VIEW



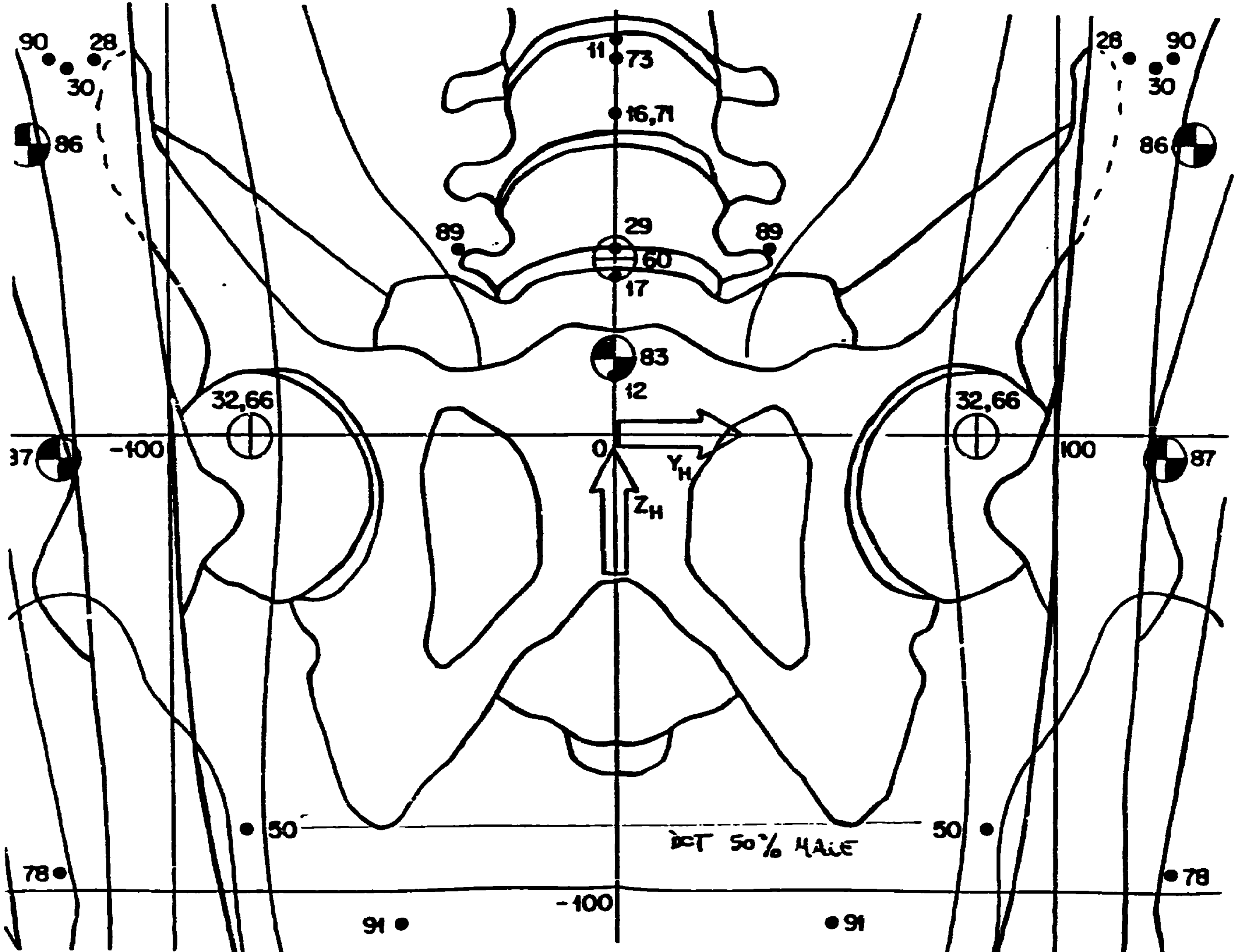
LATERAL (Right Side View)

TRISERVICE PELVIS GEOMETRY
FIGURE 15



DOT PELVIS GEOMETRY
FIGURE 16

A



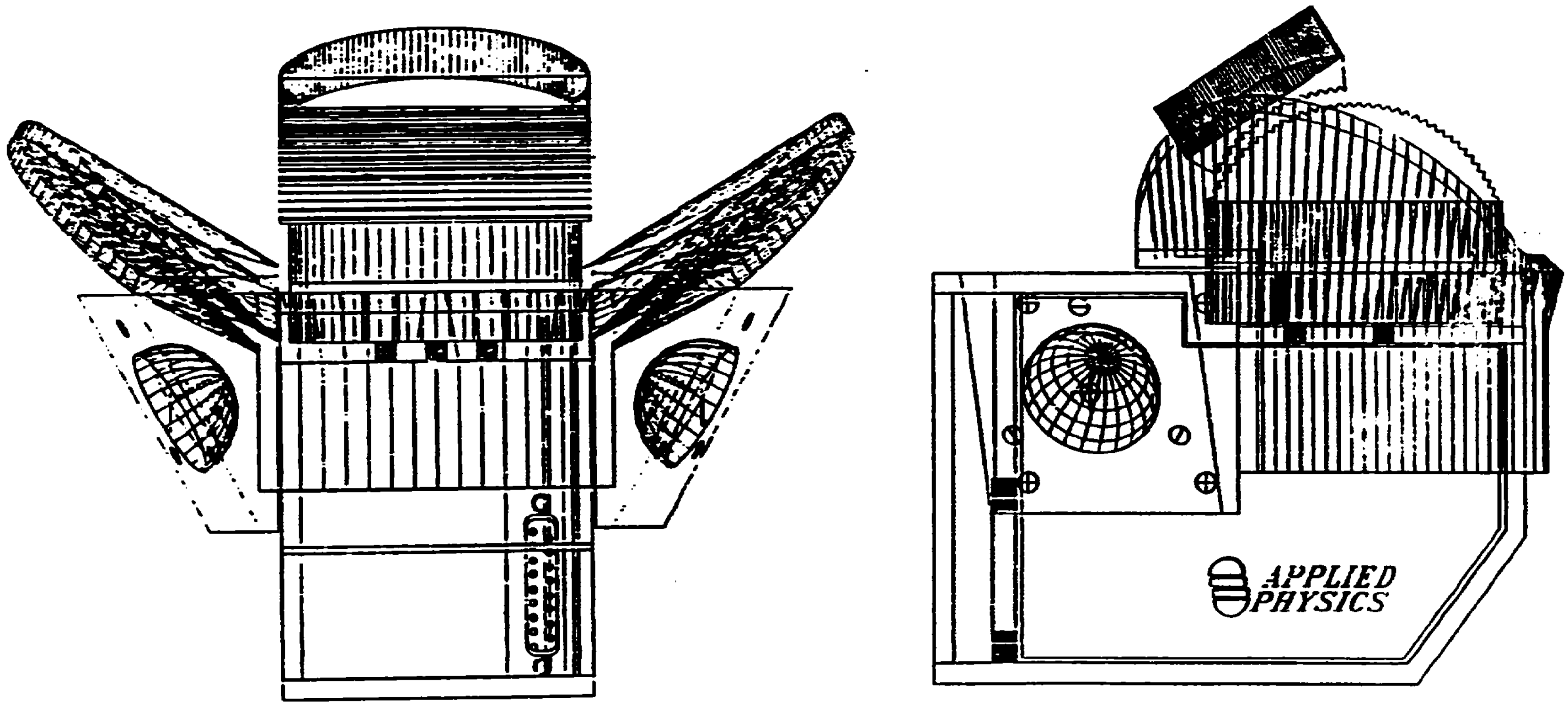
DOT PELVIS GEOMETRY
FIGURE 16

B

CORRELATION MATRIX 50 % MANIKIN

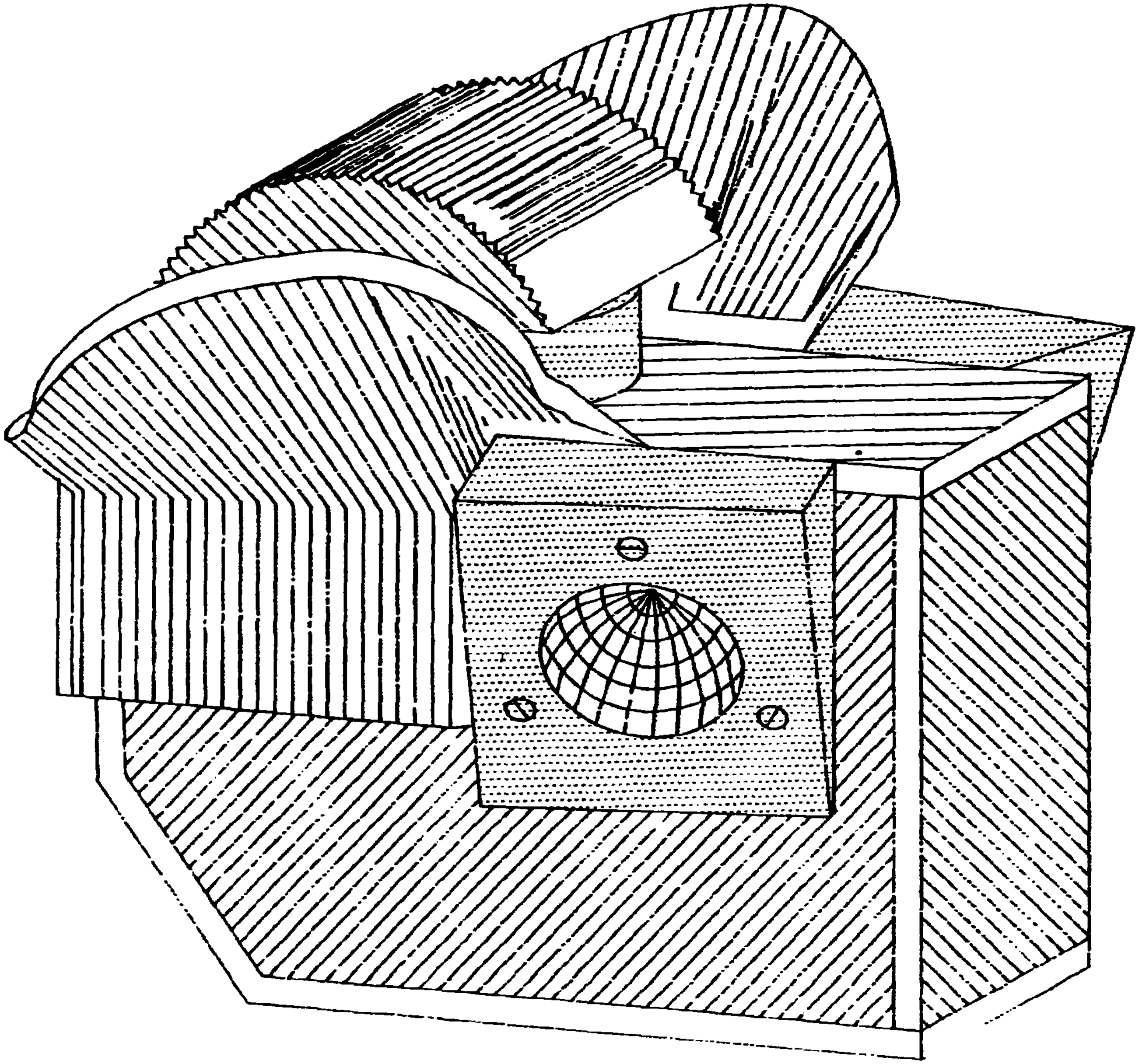
	HYBRID III	DOT	REYNOLDS	USAARL
A	11.00	9.00	10.50	11.00
B	6.875	6.50	6.187	6.875
C	2.99	2.75	3.00	3.00
D	4.19	4.25	4.00	4.35
E	2.99	2.75	3.00	3.00
F	4.31	4.187	4.50	4.625
G	8.75	6.50	6.125	6.50
H	7.20	7.875	7.00	7.50
J	3.16	1.875	2.00	2.00
K		6.00	5.25	5.50
L		4.00	4.125	4.25
M		5.00	5.125	5.50

COMPARATIVE PELVIS GEOMETRY
TABLE 2



APPLIED PHYSICS PELVIS DESIGN
FIGURE 17

A



APPLIED PHYSICS PELVIS DESIGN
FIGURE 17

electronic and integral cable harness. The leg sockets are drilled, tapped and bolted to the side plates of the pelvis and are designed to be compatible with the existing Hybrid III femur assembly. The size and position of the socket assembly can easily be altered for varying size pelvis geometries. The L5 or load cell plate bolt to the top of the pelvis positioning the axis of the load cell to align with the L5 coordinate system. As in the case of the sockets, this assembly can be repositioned, to accommodate varying geometries and load cells. The final portion of the pelvis is a aluminum casting providing the contour and shaping of the pelvis. The casting is removeable via a multiple bolting arrangement and replaceable to alter the pelvic contour.

2.5 Instrumentation Requirements

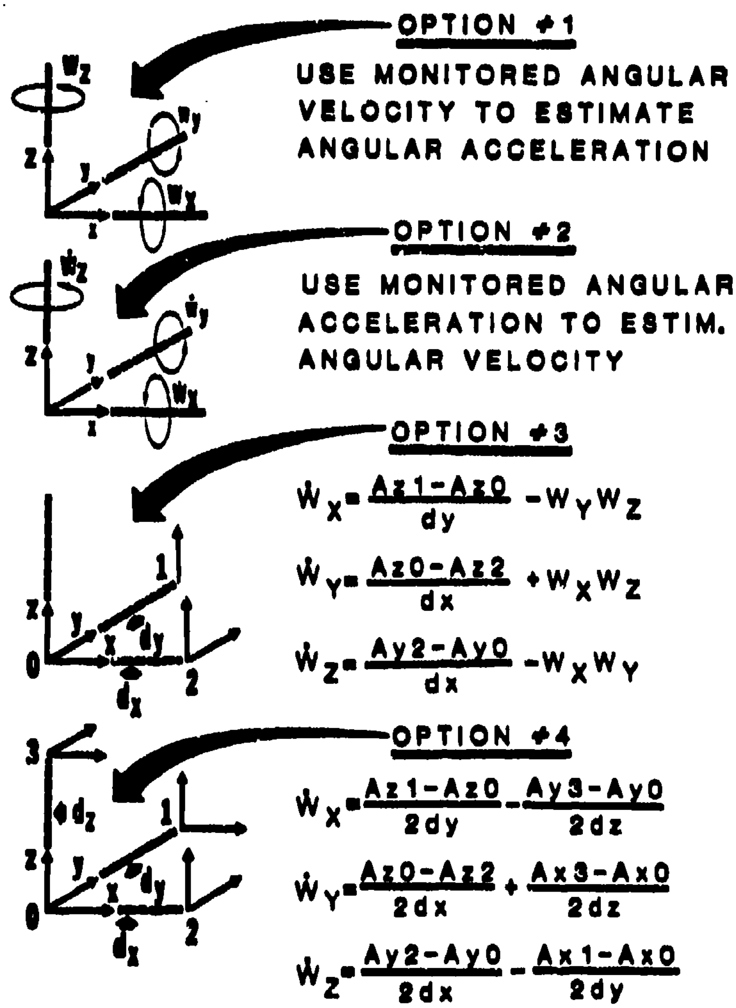
There are basically four instrumentation options available to quantify the six degree of freedom motion of the segments monitored. The first is a combination of three linear accelerometers (measuring the X, Y, and Z responses) and rate gyros measuring the angular velocities about the respective axes. Differentiation of the angular velocities provide the estimates of angular accelerations required to solve the equations of motion. In the second option, in addition to the three linear accelerometers, angular accelerations are monitored directly and the data integrated to obtain angular velocity estimates. Option 3 uses an array of six accelerometers, where angular accelerations are derived from differences in the respective linear accelerations measured, divided by the distance separating them. It should be noted that the cross terms involving the angular velocities are derived from the angular acceleration terms in the previous time step. Consequently, derivations conducted at time "t" are directly dependent on existing conditions at time "t-1." This has some solution stability implications and instrumentation packages based on such an array should not be employed in long pulse duration events. Finally, under the last option (Option 4), a cluster of nine accelerometers can be used to obtain separate estimates for both the angular accelerations and angular velocity cross terms (equations not shown) and these estimates are functions solely of differences between respective linear acceleration terms existing at time "t". This provides for increased stability over option 3 but still suffers under the experimental run time constraint, making it unappealing for ejection seat testing covering the catapult, rocket and parachute opening shock phases. Figure #18 indicates the equations for the four options, yielding the parameters necessary to resolve the equation of motion below:

$$\ddot{\bar{A}}_p = \ddot{\bar{A}}_b + \bar{w}_b \otimes (\bar{w}_b \otimes \bar{d}) + \dot{\bar{w}}_b \otimes d$$

$$\ddot{A}_{xP} = \ddot{A}_{xB} + W_{pB}(w_{rB}d_y - w_{pB}d_x) - w_{yB}(w_{yb}d_x - w_{rb}d_z) + \dot{w}_{pB}dz - \dot{w}_{yB}d_y$$

$$\ddot{A}_{yP} = \ddot{A}_{yB} + W_{yB}(w_{pB}d_z - w_{yB}d_y) - w_{rB}(w_{rB}d_y - w_{pB}d_x) + \dot{w}_{yB}d_x - \dot{w}_{rB}d_z$$

$$\ddot{A}_{zP} = \ddot{A}_{zB} + w_{rB}(w_{yB}d_x - w_{rB}d_z) - w_{pB}(w_{pB}d_z - w_{yB}d_y) + \dot{w}_{rB}d_y - \dot{w}_{pB}d_x$$



INSTRUMENTATION OPTIONS
FIGURE 18

Instrumentation packages based on all four options have been constructed and utilized by NBDL and NADC in various experiments. The accuracies of the estimates provided by the respective configurations have been cross validated and form the basis for the theoretical considerations choice of configuration for inclusion into the manikin.

Additionally, commercial six element load cells as available from Denton Inc., have been employed in femur instrumentation, as well as in the neck and pelvic regions of the Hybrid II and III manikins. The small size and performance make these sensor reasonable candidates in monitoring the responses of the proposed manikin.

It is proposed that the manikin be instrumented as defined in Table #3 and illustrated in Figure #19.

2.6 Sensors

Linear Accelerometers

For linear acceleration, piezo resistive miniature accelerometers have been routinely used by both the automotive industry and the military for escape system testing. Both Entran and Endevco manufacture suitable configurations, making them ideal candidates for manikin instrumentation due to their size, weight and low power consumption characteristics. Additionally, their adoption poses no risk, since they have been extensively employed in the environment under discussion.

It is recommended that the Entran EGA-125 series miniature accelerometers be utilized. The EGA-125 is a piezo resistive device utilizing a fully active semiconductor Wheatstone bridge providing a high output enabling the EGA to directly interface with monitoring systems. The sensors are fully compensated for temperature changes within the environment. The EGA-125 is functional from steady state to high dynamic responses and is ranged for "G" loads ranging from 5G to 5000G. The EGA specification and configurations are illustrated in Figure #20.

Angular Accelerometers

The utilization of the Endevco Angular Accelerometers Model 7302B is proposed for the measurement of angular acceleration. The 7302B are piezo resistive devices measuring torsional vibration. The unit is unaffected by linear shocks upto 2500G or by angular shocks by 10 times the over range. The sensor provides temperature compensation upto temperatures of 250°F. These sensors have been utilized at NBDL as reported by Wilhems.[17] The specification and mechanical configuration of Endevco Model 7302B is illustrated in Figure #21.

Review of 7302B sensor performance at NADC (Dr. Philip Whitley) has revealed some problems in the repeatability of measurements at the angular accelerations of interest. The performance of these sensors must be further investigated during phase II prior to any cost commitments.

<u>Minimum Sensor Configuration</u>

Channel 1	$Head_x$ Lin. Accel	
Channel 2	$Head_y$ Lin. Accel	Located at head c.g.
Channel 3	$Head_z$ Lin. Accel	
Channel 4	$Head_y$ Angular Accel	Located <u>near</u> head c.g.
	$Head_x$ Angular Accel	Provide angular accel
	$Head_z$ Angular Accel	connectors only
Channel 5	C_1-C_2 Force along Z Axis (F_z)	Located at centroid
Channel 6	C_1-C_2 Force along X Axis (F_x)	of C_1-C_2 joint
Channel 7	C_1-C_2 Mom about Y Axis (M_y)	
	C_1-C_2 Mom about Z Axis (M_z)	
	C_1-C_2 Force along Y Axis (F_y)	Load cell connectors
	C_1-C_2 Mom about X Axis (M_x)	only
Channel 8	C_7-T_1 Lin. Accel along X (A_x)	Locate at forward
Channel 9	C_7-T_1 Lin. Accel along Y (A_y)	edge of vertebra
Channel 10	C_7-T_1 Lin. Accel along Z (A_z)	centrum
Channel 11	C_7-T_1 Force along Z Axis	
Channel 12	C_7-T_1 Force along X Axis	Locate at spinal
Channel 13	C_7-T_1 Mom about Y Axis	column centroid
Channel 14	C_7-T_1 Mom about X Axis	
	C_7-T_1 Force along Y Axis (F_y)	Load cell connectors
	C_7-T_1 Mom about Z Axis (M_z)	only
	T_1-T_{10} Provide space only for easy retrofit (6-channel load cell)	
Channel 15	Sternum X displacement (S_x) at T_6 attachment point	
Channel 16	Sternum Lin. Accel A_z	Locate at T_6 intercept
Channel 17	Sternum Lin. Accel A_x	with sternum
Channel 18	L_5-S_1 Force along Z (F_z)	
Channel 19	L_5-S_1 Force along X (F_x)	Locate at spinal
Channel 20	L_5-S_1 Mom about Y axis (M_y)	column centroid
Channel 21	L_5-S_1 Mom about Y axis (M_x)	
	L_5-S_1 Force along Y (F_y)	Load cell connectors
	L_5-S_1 Mom about Z (M_z)	Only
	$L_5-S_1-A_x,A_y,A_z$ Lin. accel	Mount provisions only at forward edge of vertebra centrum

- Linear accelerometers, ±100 g for torso
  Linear accelerometers, ±500 g for head

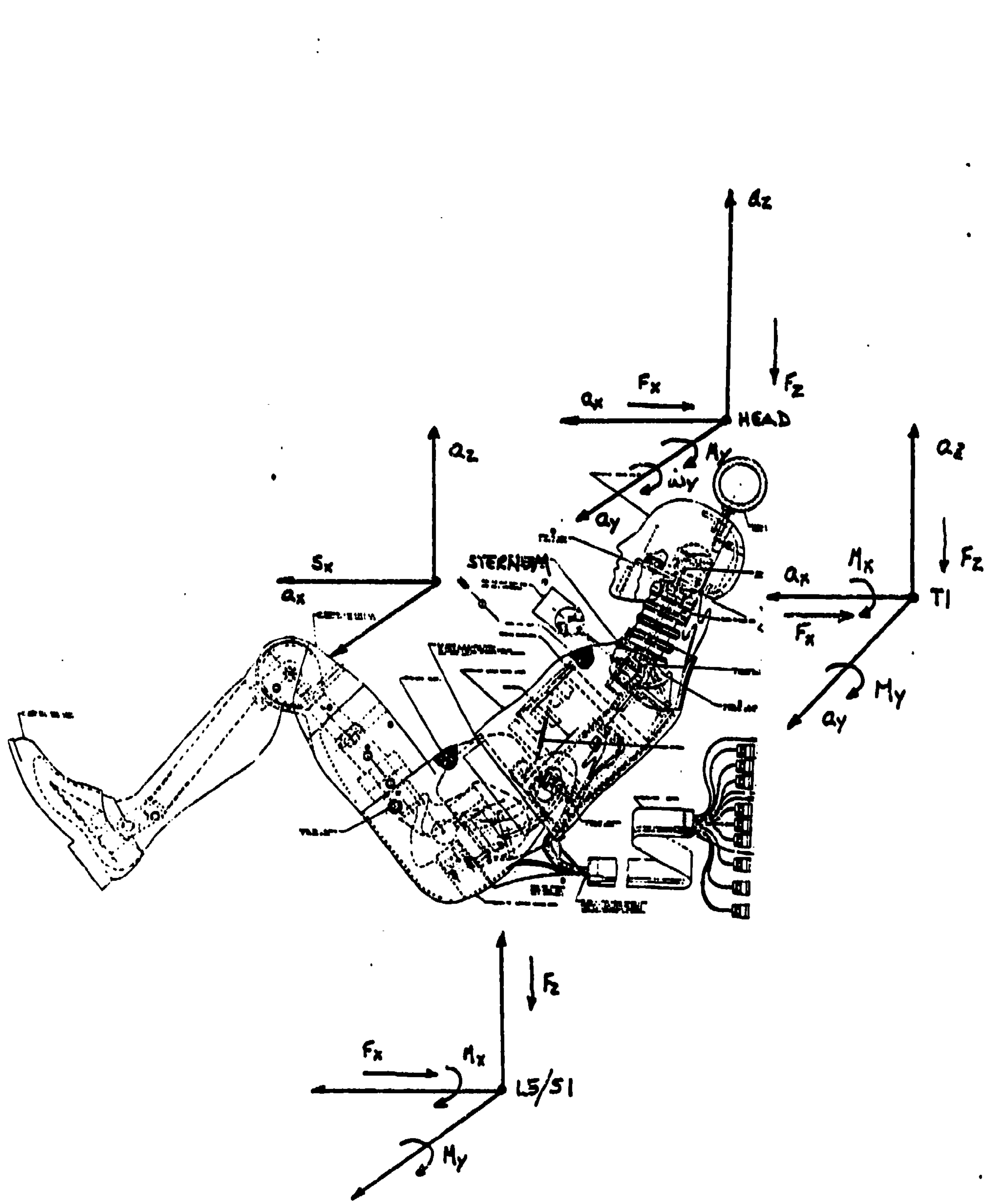
- Angular accelerometers, 12,000 rad/sec²

- Force/load values

  Lower spine compression, 6,000 pounds
  Upper spine compression, 2,000 pounds
  Leg bone compression, 3,000 pounds

SENSOR INSTRUMENTATION

TABLE 3



SENSOR INSTRUMENTATION
FIGURE 19

SPECIFICATIONS

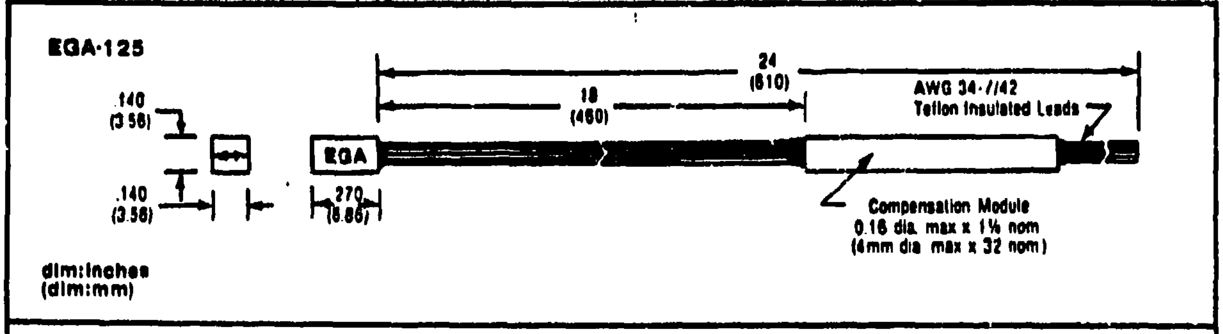
MODEL	EGA-125-5	*EGA-125-10	EGA-125-25	EGA-125-50	*EGA-125-100	*EGA-125-250	EGA-125-500	EGA-125-1000	EGA-125-2500	EGA-125-5000
RANGE	±5g	±10g	±25g	±50g	±100g	±250g	±500g	±1000g	±2500g	±5000g
[2,3] OVERRANGE	±25g	±50g	±125g	±250g	±500g	±1250g	±2500g	±3000g	±5000g	±10000g
SENS. mV/g nom.	15	12	5	4	2.5	1	0.5	0.25	0.1	0.05
[1,3] RES. FREQ. nom.	300 Hz	500 Hz	1000 Hz	1200 Hz	1500 Hz	2000 Hz	3000 Hz	4000 Hz	6000 Hz	8000 Hz

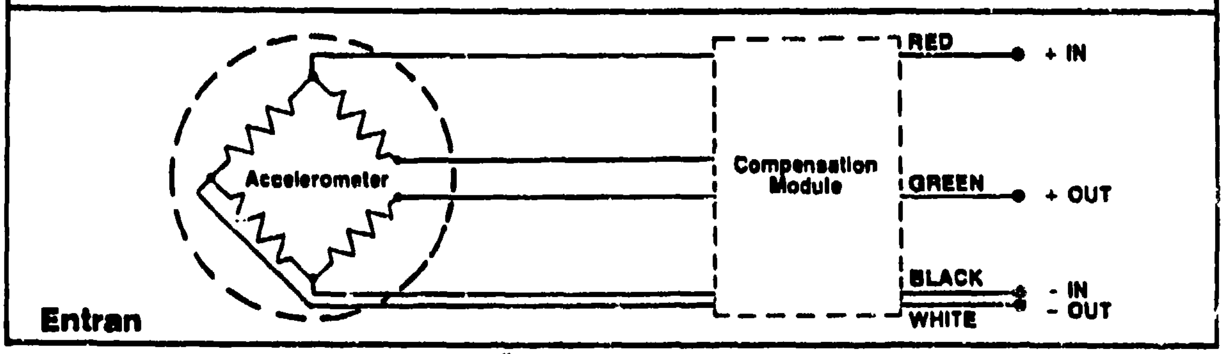
* "OFF-THE-SHELF" STOCK IN EGA-125-10D, -100D AND -250D AND EGA-125F-10D, -100D AND -250D DAMPED VERSIONS.

NON-LINEARITY	±1%
TRANSVERSE SENS.	3% max.
THERMAL ZERO	[4,5] ±1%F.S/100°F
THERMAL SENS.	±2½%/100°F
WEIGHT	½ gram nom. (w/o leads)

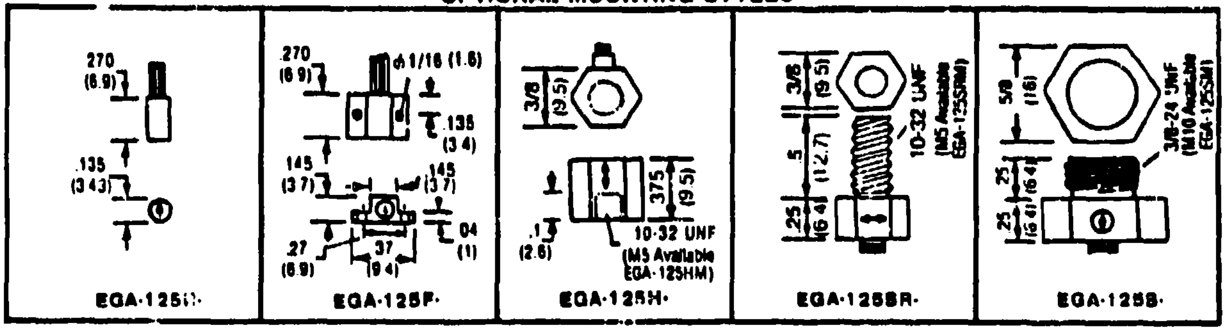
INPUT IMPEDANCE nom.	1000 Ω typ.: 2000 Ω optional (500 Ω min.) with 900 Ω output
OUTPUT IMPEDANCE nom.	450 Ω: 900 Ω optional with 2000 Ω input
EXCITATION	[6] 15VDC
COMPENSATED TEMP.	70°F to 170°F (21°C to 77°C) OPTION "Z": 32°F to 140°F (0°C to 60°C)
OPERATING TEMP.	[6] -40°F to 250°F (-40°C to 121°C)

[1]Useful frequency range is 20% of Resonant Frequency [2]Overrange for use within 30% of Resonant Frequency [3]Available with 0.7cr damping to increase useful range as high as 50% of resonance with overrange at all frequencies (see Bulletin EGDAMP). [4]Zero offset of ±15mV max at 80°F after warm-up. Lower values available on request. [5]±2½%F.S./100°F for 5g Model [6]Other Excitations and Temperature Ranges available on request.



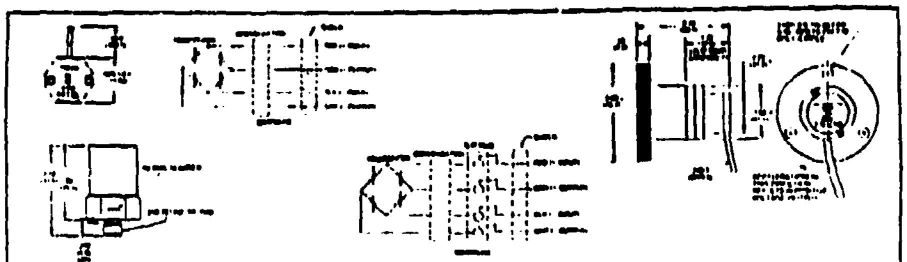


OPTIONAL MOUNTING STYLES



LINEAR ACCELEROMETER

FIGURE 20



DIMENSIONS IN INCHES (MILLIMETRES)

SPECIFICATIONS FOR MODELS 7302B AND 7302BM1 ACCELEROMETERS

DYNAMIC	
Sensitivity (at 10 Vdc)	4.0 µV per rad/s² typical, 3.0 to 5.5 µV per rad/s²
Full Scale	50 000 rad/s²
Amplitude Linearity	Data suggest that sensitivity at full scale is ±1% relative to sensitivity at 1000 rad/s². Measurement uncertainties prevent stating this as a specification limit
Mounted Resonance Frequency	2700 to 3300 Hz, 3000 Hz typical
Frequency Response	±4%, 1 Hz to 600 Hz, typical, reference 100 Hz
Phase Response	Typical of 0.05 critically damped single-degree-of-freedom system
Transverse Angular Sensitivity	3% maximum
Linear Acceleration Sensitivity	Data suggests direct proportionality with frequency below 600 Hz, and a value of less than 1.0 equivalent rad/s² per g in any direction at 100 Hz. Measurement uncertainties prevent stating this as a specification limit.
Sensitivity Deviation Due to Temperature	Temp: 0°F, 125°F, 200°F — Typical: ±3% from average — Maximum: ±6% from average
ELECTRICAL	
Excitation	10.0 Vdc, 14 Vdc maximum
Electrical Configuration	Four-active-arm piezoresistive bridge
Polarity	Positive output for counterclockwise acceleration of mounting surface, as viewed from the top
Input/Output Resistance	2400Ω/1600Ω typical
Insulation Resistance	100 MΩ between pins and pins to case. Case is grounded
Zero Measurand Output	±50 mV maximum
Background Noise	10 µV rms
PHYSICAL	
Weight	35 grams
Case Material	Stainless steel
Mounting	1/4-28 integral stud. Recommended mounting torque 10 lb-in (1.1 N·m)
Moment of Inertia	Approximately 0.00015 oz-in-s² (10 gram-cm²)
ENVIRONMENTAL	
Temperature	0°F to +250°F (-18°C to +120°C) continuous operation
Shock — Angular Acceleration	500 000 rad/s²
Shock — Linear Acceleration	2500 g
Humidity	Hermetically sealed with all-welded case

Continued product improvement necessitates that Endevco reserve the right to modify these specifications.

RELIABILITY: Endevco maintains a program of constant surveillance over all products to ensure a high level of reliability. This program includes attention to reliability factors during product design, the support of stringent quality control requirements, and compulsory corrective action procedures. These measures, together with conservative specifications, have made the name Endevco synonymous with reliability. Endevco's Quality and Reliability system meets the requirements of MIL-Q-9858A and MIL-STD-785A.

CALIBRATION: Each unit is calibrated at 100 Hz and 1000 Rad/s² for sensitivity, at 80°F, 125°F and 200°F for sensitivity deviation due to temperature, and from 30 Hz to 800 Hz for frequency response.

ENDEVCO CORPORATION — DYNAMIC INSTRUMENT DIVISION

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ANGULAR ACCELEROMETER
FIGURE 21

As an alternative, both the 6 and 9 linear accelerator clusters could be utilized as documented by Becker and Willems[18]. Additionally, the DART units used by NADC and NBDL could be substituted. These are of course not solutions of choice, but will resolve the problem, at some additional cost.

Load Cells

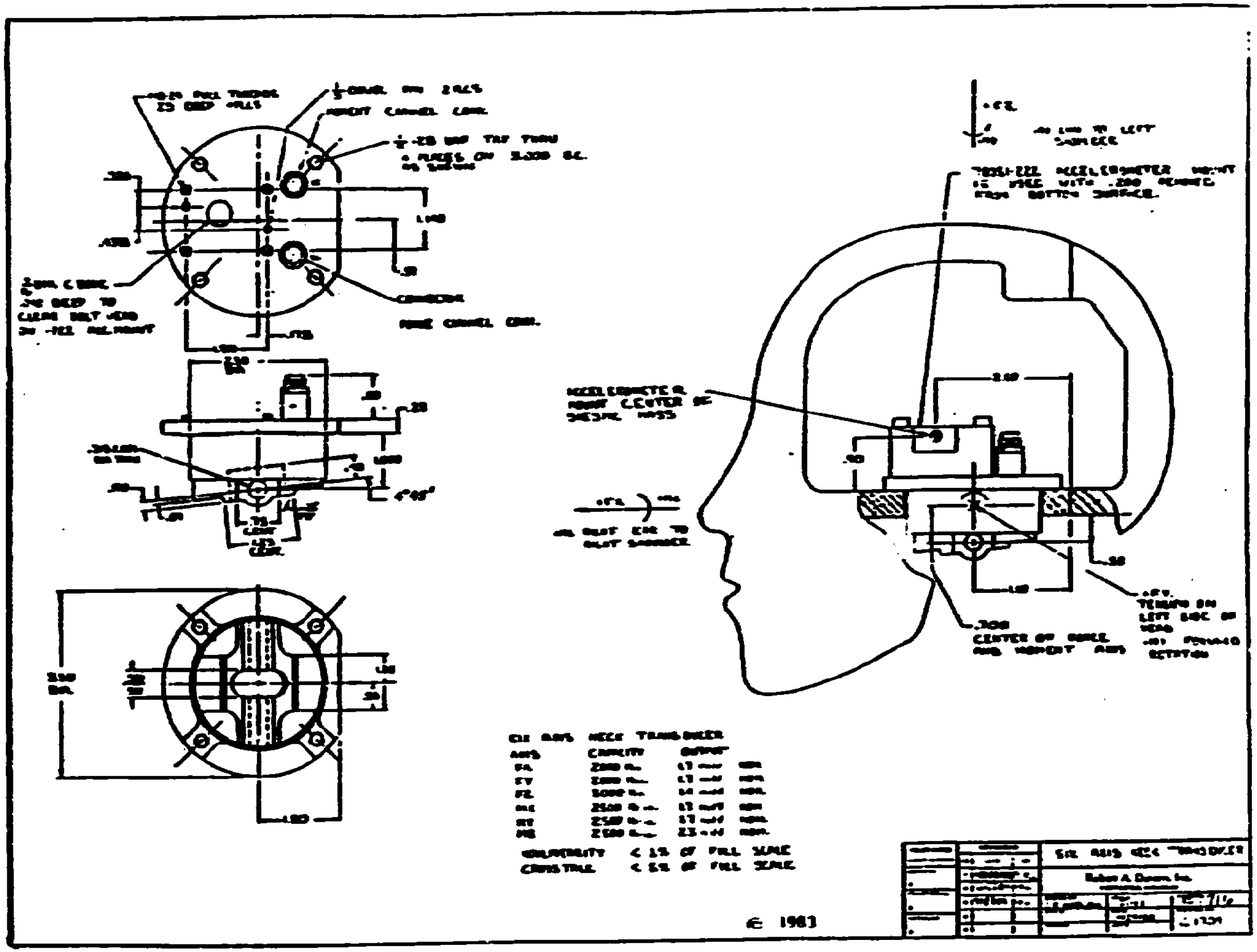
It is recommended that the load cell requirements of this program be satisfied utilizing the Denton series of six axis transducers commonly utilized in both the automotive and aerospace environments. The six axis neck transducer (Denton C1709) is illustrated in Figure #22. The load cell is designed to be compatible with both the Hybrid II and Hybrid III head and neck assemblies. The C1709 mounting will be redesigned for inclusion at approximately T1 and T10-T12 locations. The T10-T12 position will be substituted with a spacer, for future inclusion of the load cell. The lumbar 6 axis load cell will be implemented via a Denton C1708 as illustrated in Figure #23.

2.7 System Architecture

In order to quantitatively measure the biodynamic response of the proposed manikin system, it is necessary that a high speed, real time data acquisition and storage system (DASS-II) be incorporated as an integral part of the manikin design and development. The proposed system configuration is generally illustrated in Figure 24. As indicated, the system is distributed throughout the manikin, the processor subsystem within the chest cavity, the analog subsystem within the enhanced pelvic assembly and the battery assembly within the legs. This redistribution of the DASS-II enables the biodynamic response characteristics of the manikin to be maintained, while simultaneously providing the extensive electronics necessary to measure and record the responses.

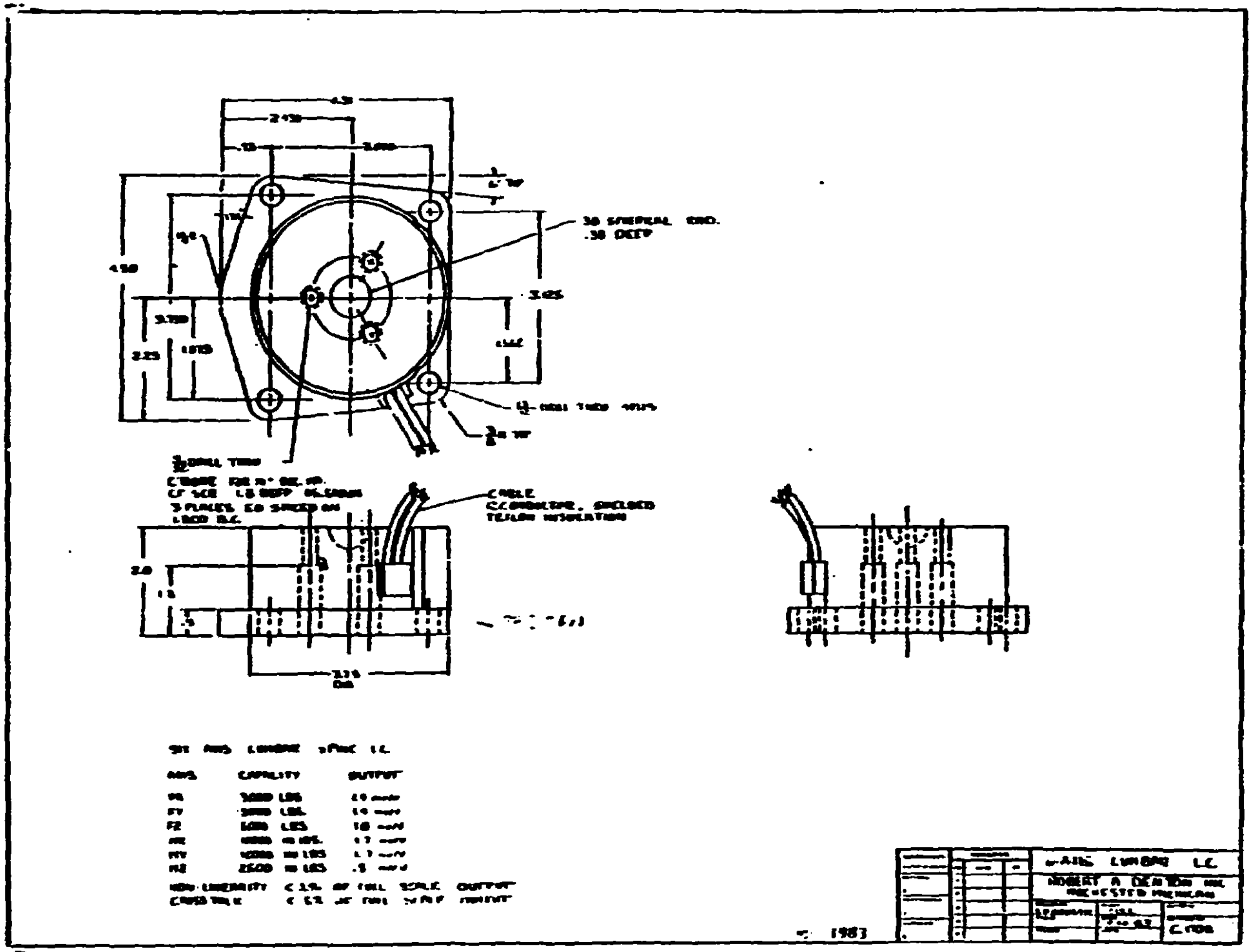
The recommended system architecture is illustrated in Figure #25. As indicated, the system is subdivided into three manikin internal components; analog subsystem, processor subsystem and power distribution subsystem, and a external user interface/support IBM portable or laptop computer. The processor subsystem is based on a CMOS 80286 processor, with addressing capabilities of upto 16Mbytes (2Mbytes provided), serial communication (RS232) and all digital timing and input/output logic necessary to control the DASS-II operation. The analog subsystem contains all signal conditioning circuits, multiplexing and analog to digital conversion to support upto 48 channels.

Each analog channel contains a dedicated analog signal conditioning path as illustrated in Figure #26. Each channel supports a differential instrumentation amplifier with a variable, CPU programmable sampling frequency and gain maintaining a full scale signal at the A/D converter. Connected to the amplifier is a anti-aliasing filter, providing a CPU adjustable 500 hertz cutoff and a minimum rolloff characteristic of -45 db/octave. The filter is coupled to a dedicated sample and hold circuit, time synchronized with all other channels. The analog channels are multiplexed to provide two parallel analog input paths to the A/D converters. The A/D's are high speed, biopolar input converters maintaining 12 bit resolution.



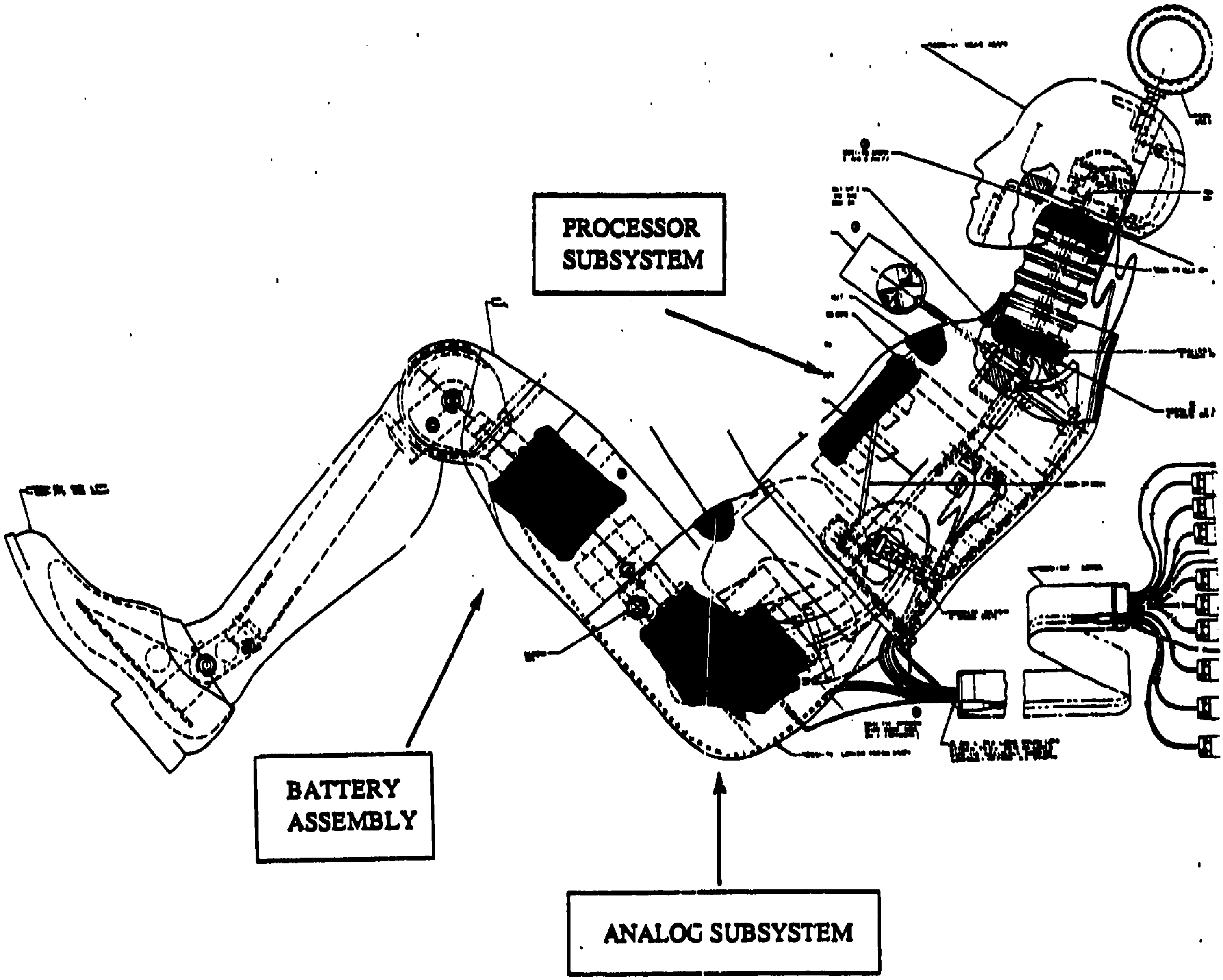
DENTCN C1709 LOAD CELL

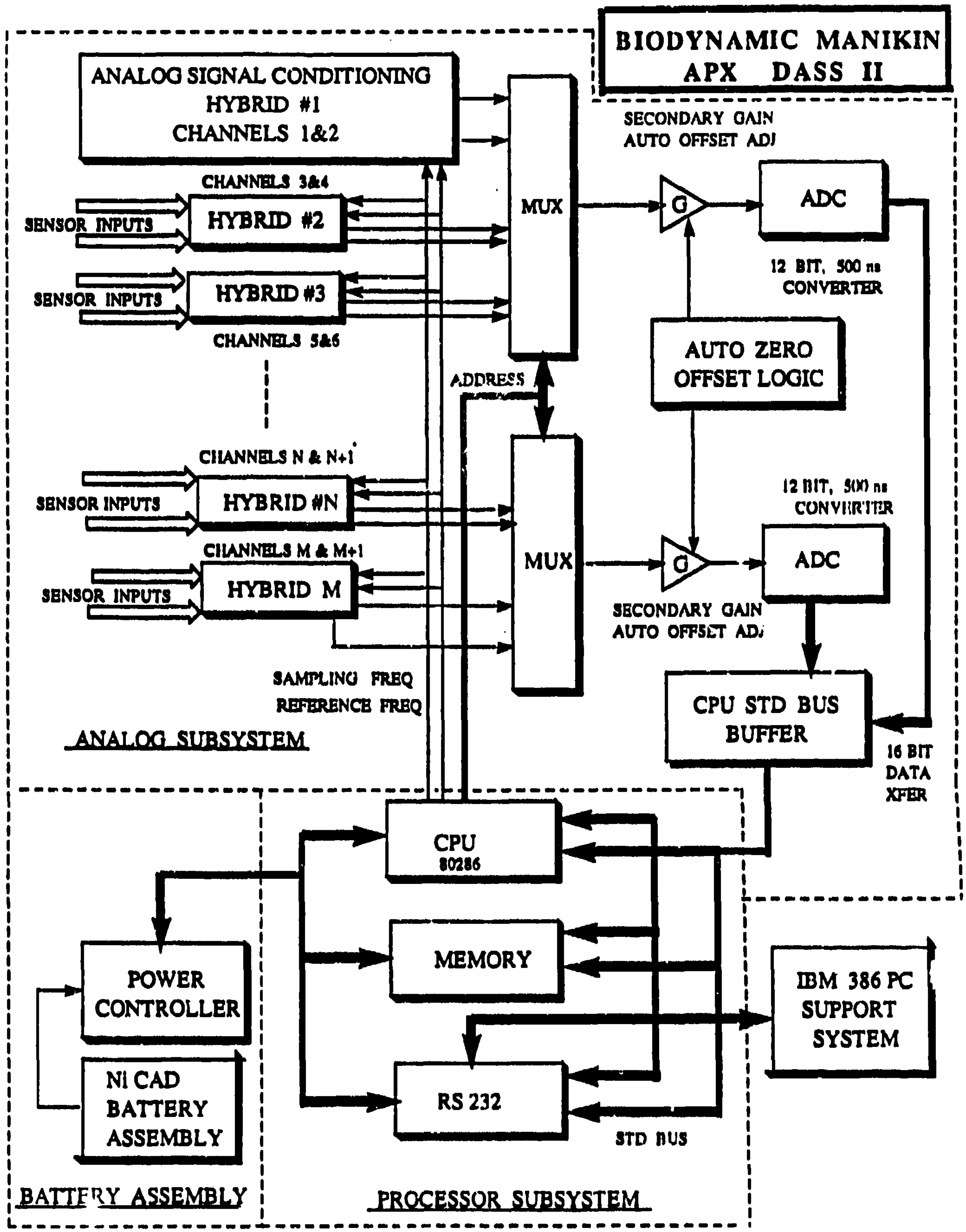
FIGURE 22



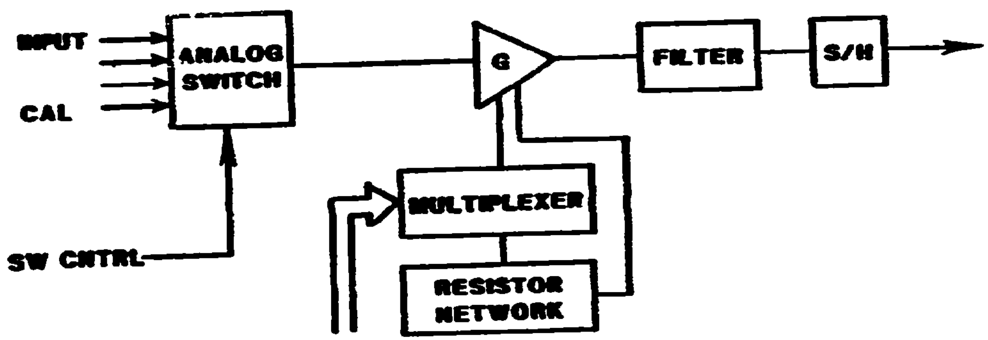
DENTON C1709 LOAD CELL
FIGURE 23

DASS - II ARCHITECTURE
(GENERAL)
FIGURE 24





DASS-II ARCHITECTURE
(DETAILED)
FIGURE 25



SINGLE CHANNEL OF QUAD SIGNAL CONDITIONING HYBRID.

SPECIFICATIONS:

PROGRAMMER GAIN	1 TO 100
FILTER CUTOFF	MAX 20KHz
FILTER ROLLOFF	42 dB/OCTAVE
SAMPLING FREQUENCY	MAX 10KHz
PROCESSOR	HIGH-DENSITY HIGH PERFORMANCE SILICON GATE (HCMOS): - BIT
OPERATIONAL VOLTAGE	5V TO 5.5V (MICROCOMPUTER) 5V TO 15V (SIGNAL CONDITIONING)

ANALOG SIGNAL PATH

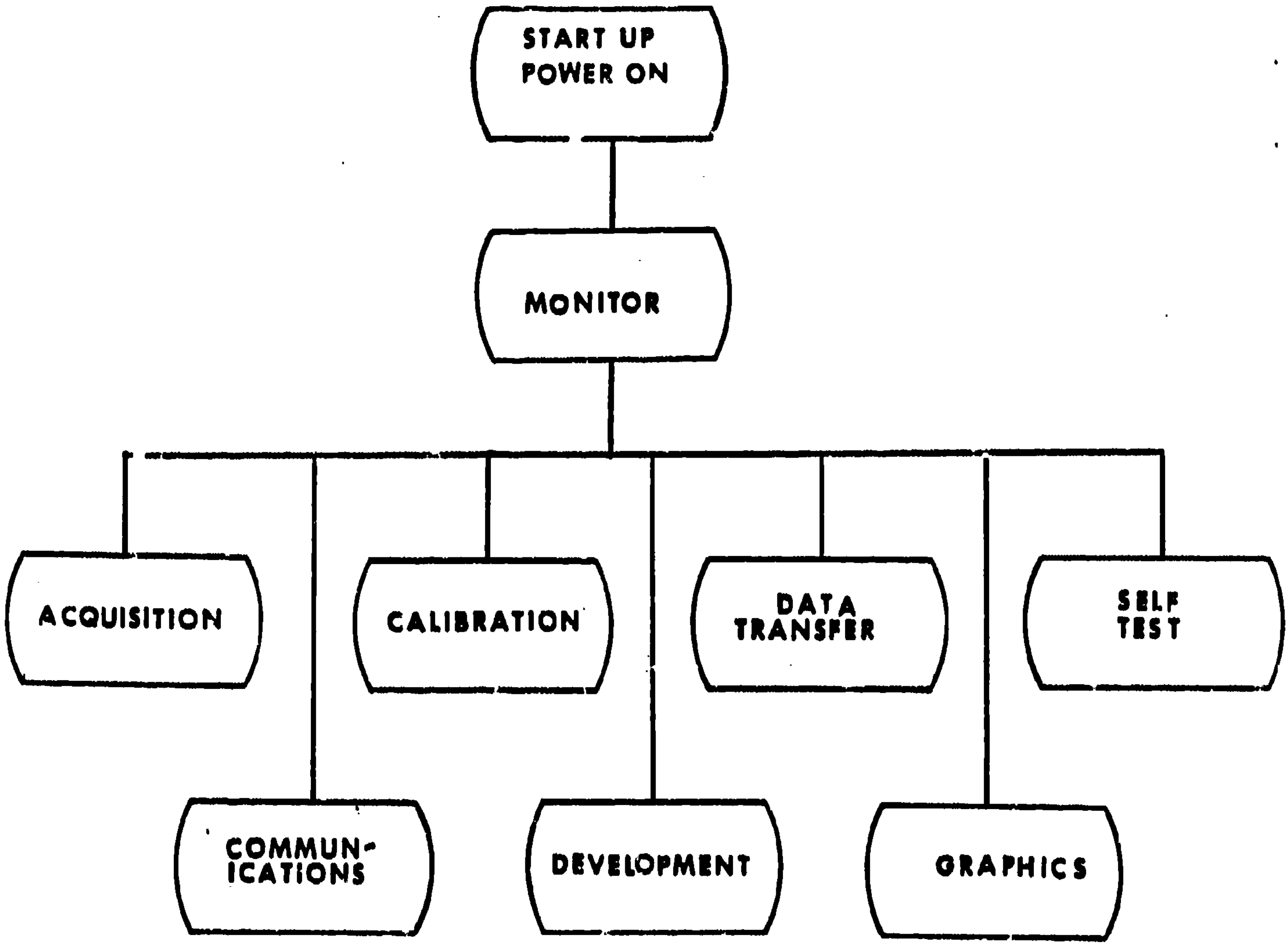
FIGURE 26

The converter function and multiplexer addressing (selection of sensor input) will be under processor control. The parallel A/D path provides a packed 3 byte data package (12 bits/channel) maximizing RAM utilization (RAM utilization will be critical due to size, power, density constraints). The power subsystem provides the battery source (NiCAD battery packs) and circuitry necessary to power manage the system, maximizing power utilization and recharging. The laptop IBM, external to the manikin provides the user interface to system, enabling the user to configure, test and evaluate the system performance. Additionally, the IBM provides the mass storage media to offload post experiment data, for processing and analysis.

The DASS-II function is defined by the assembly language operating software, programmed into ROM. The software is structured as illustrated in Figure #27, defining the full operation of the system.

Upon power up, the DASS-II processor enters a preflight mode updating all status registers, memory pointers, communication ports, and hardware latches. The preflight software establishes communications with the user/support computer, determining the variable experiment dependent characteristics such as sampling frequency, number of channels, sensor type and the sensor characteristics. Software developed on the DASS-II processor and IBM will perform a handshake that relays requested data to the requesting processor. Upon completion of preflight functions, the DASS-II returns to the system monitor, awaiting function mode selection from the user interface. The calibration software provides a means of measuring the errors introduced from the sensor through all components of the system. The system supports two modes of calibration, voltage substitution and shunt. In the shunt (RCAL) mode, the processor shunt loads each sensor with a known resistive load, measuring the sensor output at the A/D and storing results. In the automatic mode, the calibration software provides a voltage substitution scheme simulating the range of analog inputs into each channel. The system additionally maintains the capability to perform pre and post experiment calibrations.

The data acquisition software is based on an interrupt architecture, where an interrupt pulse is generated at the desired data sampling frequency. The interrupt based acquisition is enabled by start of experiment signal and provides the hold signal to the sample and hold circuits, time synchronizing all channels. Each interrupt triggered acquisition cycle will start the A/D conversion process, and subsequently input data from the two parallel converters, storing the packed 3 bytes sequentially into memory. Each sampling interaction blocks all corresponding channel data with preceding elapsed time data and a post data separator. Acquisition is terminated and returns to the system monitor automatically when either the maximum experiment time or available memory has been exceeded. The system software provides for diagnostics and self test capabilities to verify system hardware and software operation. Sensor and signal conditioning circuits are tested using a process similar to that detailed for calibration. The software checks selected portions or the complete RAM memory, writing data to each location and successfully retrieving the data. The timing (interrupt, sample and hold) signals are verified prior to experiment. Communications with the user interface and the offload device (RS232) are additionally verified.



SOFTWARE ARCHITECTURE
FIGURE 27

The communications software will provide the link between the DASS-II and IBM interface, via a serial RS232 port shared by both processors. Each processor operates asynchronously, monitoring and relaying information based on received ASCII function codes. Relaying of diagnostic and calibration data is achieved in a similar manner with the remote unit loading the code, and the DASS providing the data via the RS232 interface.

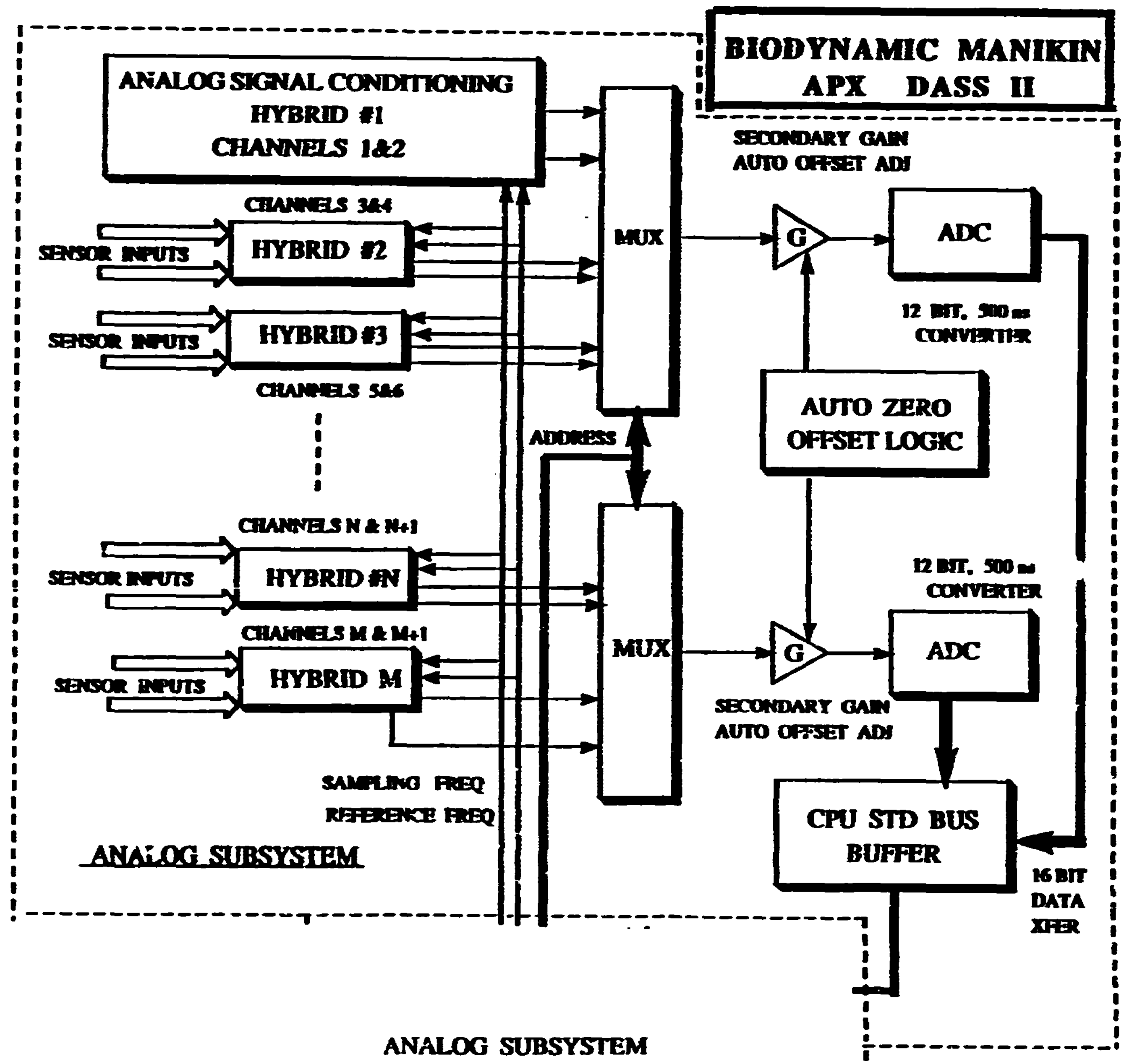
32.8 Analog Subsystem

The analog subsystem is housed within the enhanced pelvis and is generally illustrated in Figure #28. This subsystem consists of all the circuitry necessary to signal condition the sensor inputs of upto 48 analog channels (24 provided). The subsystem is divided into 4 distinct analog signal conditioning modules, each housing 12 channels. Integrating with the four signal conditioning modules, is a timing and control module providing the interface of the analog channels to the processor subsystem computer bus.

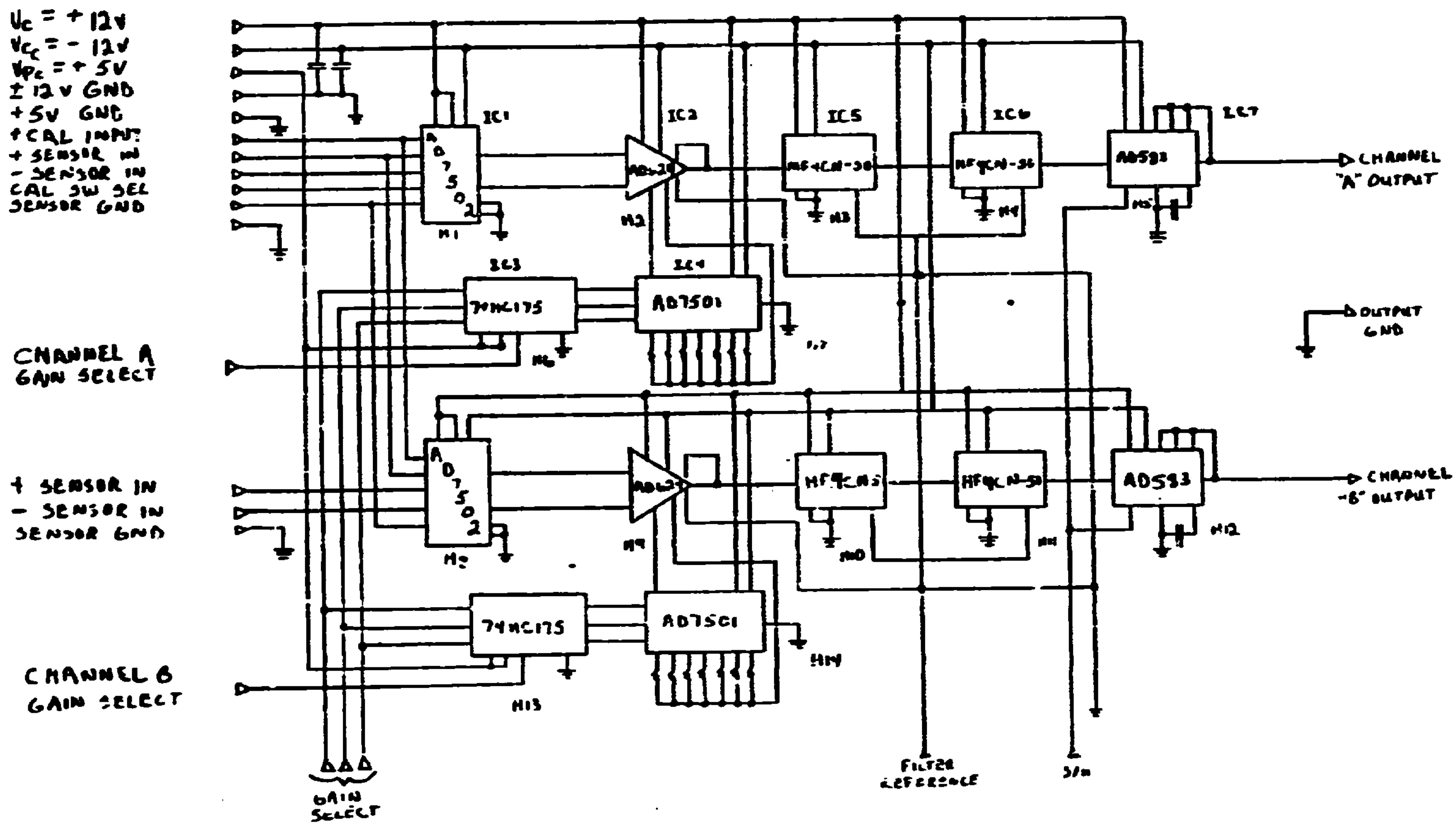
2.8.1 Hybridized Analog Signal Conditioning Path

As outlined, channel is supported by a dedicated signal conditioning path illustrated in Figure #26, and implemented via dual channel signal conditioning hybrids, developed by Applied Physics (AP-1000SC3). Each hybrid supports a variable. CPU programmable gain, a tunable cutoff frequency and roll-off characteristic of -42 dB/octave and dedicated sample and hold circuit time synchronized with all the other channels. The hybrid supports the ability to perform shunt (RCAL) calibration, offset adjustment and setting of an external precision gain. The hybrid brings key inputs and outputs to the hybrid case for testing. Additionally, errors resulting from thermal effects on mismatched components is minimized to the precise dice and materials utilized.

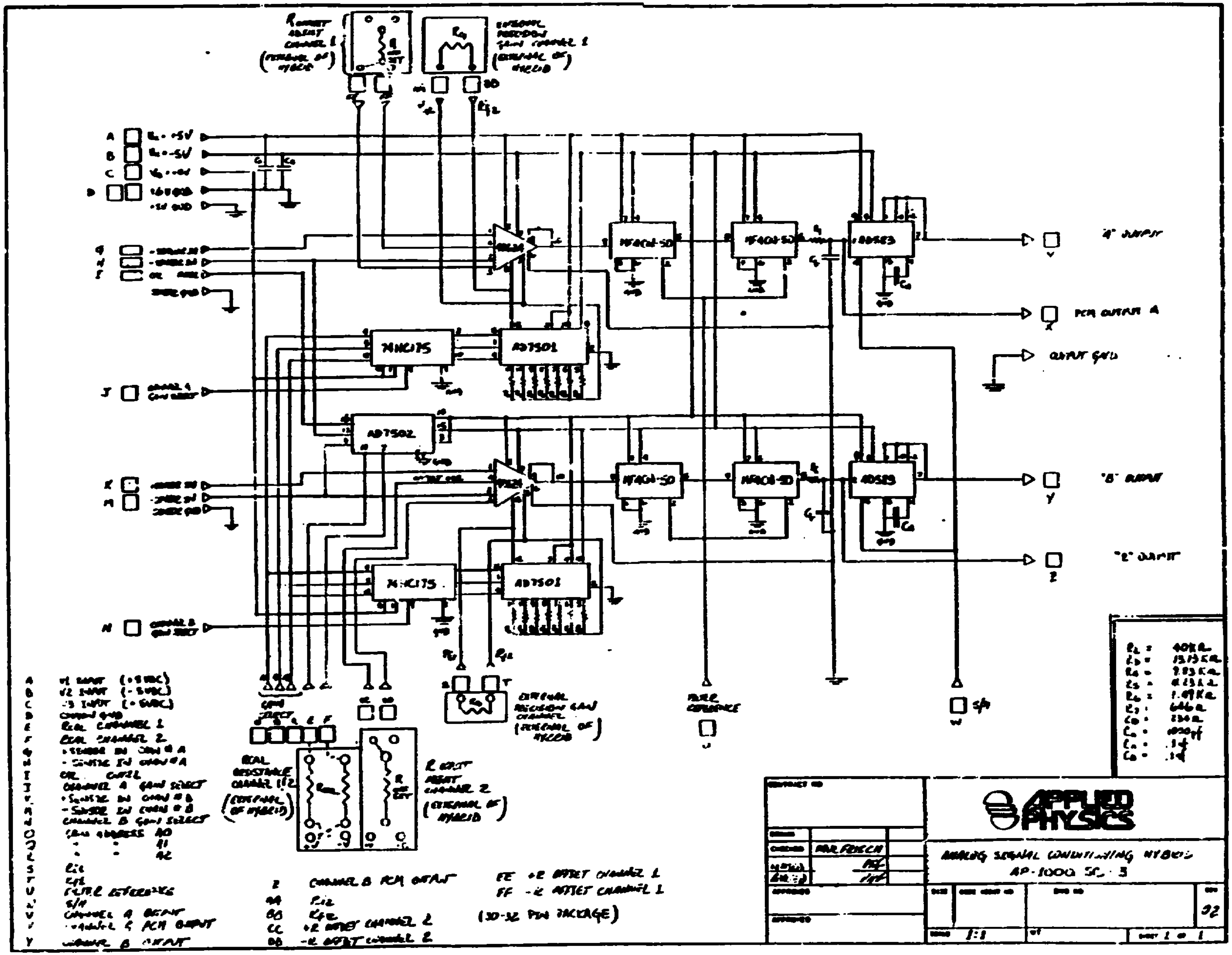
Functionally, the hybrid is illustrated in Figure #29, and detailed in Schematic #1, representing the dual channel analog signal path. Referencing Schematic #1, each channel supports a differential input precision instrumentation amplifier (U1:U8). The amplifier (Analog Device AD624) provides a high input impedance, low offset and drift, low nonlinearity, low output impedance, a slew rate exceeding slew rates of the typical sensor utilized and a bandwidth matched to sensor bandwidths. The amplifier is programmable in seven discrete gain steps (1,2,4,5,10,25,50) by varying the gain resistance via the latched gain-select multiplexer network (U5, U6:U12, U13). The gain address A0, A1, A2, along with the channel select A or B are generated by the processor subsystem. The amplifier output is provided to a cascade filter network (U2, U3; U9, U10) implementing a 8 pole Butterworth filter configuration. The low pass filter is based on switched capacitor technology supporting a programmable filter cutoff frequency ranging from .1Hz to 20 KHz, tuneable based on a reference frequency input provided from the processor subsystem. Additionally, the filter provides a fixed rolloff of -42 dB/octave. The filter output is provided to a channel dedicated sample and hold (U4; U11), which is used to time synchronize all the analog subsystem channels. Both the filter outputs and S/H outputs can be provided to the hybrid case, for PCM applications and multiplexing into an A/D multiplexer network. The hybrid provides for internal power



ANALOG SUBSYSTEM
FIGURE 28



HYBRID
FIGURE 29



ANALOG SIGNAL CONDITIONING HYBRID

SCHEMATIC # 1

decoupling and grounding and supports for external resistors to provide offset adjustments (ROFFSET), shunt or RCAL (RCAL) and external gain selection (Rg).

The functional characteristics of the Hybrid Applied Physics AP-1000SC3, can be outlined in the following specifications:

I. Amplifier Stage Characteristics

a. Low Noise	0.2 UV p-p,0.1Hz-10 Hz
b. Low Gain TC	5 ppm max
c. Low Nonlinearity	.001% max (Gain=1 to 200)
d. High CMRR	130 db
e. Low Input Offset Voltage	0.25 uV max
f. Low Voltage Drift	0.25 uV/°C max
g. Gain Bandwidth	25 MHz
h. Programmable Gain	1,2,4,5,10,25,50 external
i. Input Range	±5 VDC

II. Filter Stage Characteristics

a. Switched Capacitor Butterworth	Implementation
b. Programmable Filter Cutoff	0.1 Hz-20 KHz
c. Cutoff Frequency Accuracy	± .3%
d. Filter Rolloff	-42 dB/octave

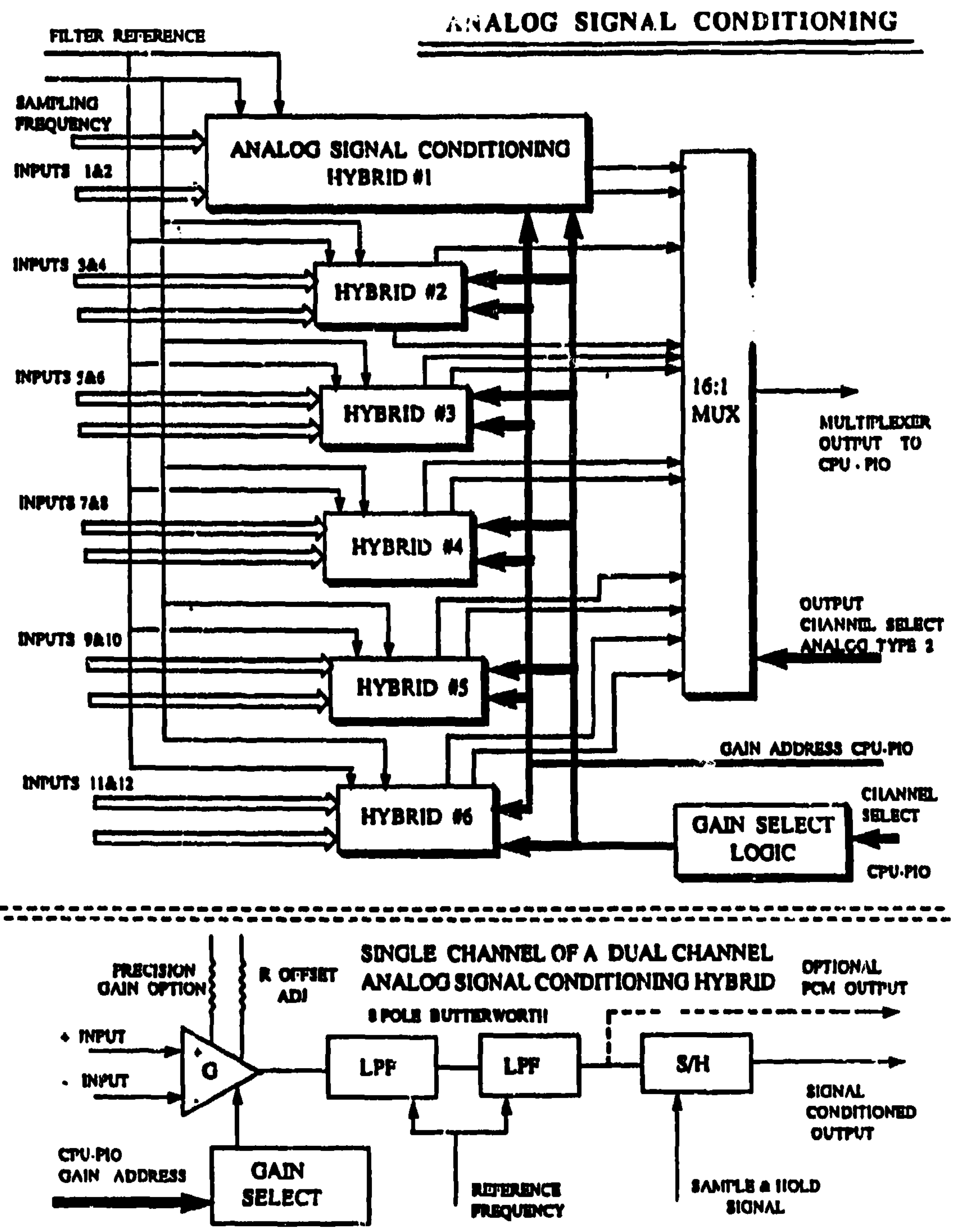
III. Sample and Hold Stage

a. High Sample-to-Hold Current Ratio	10^6
b. High Slew Rate	5 V/us
c. High Bandwidth	2 MHz
d. Low Amperture Time	39 ns
e. Low Charge Transfer	10 pC

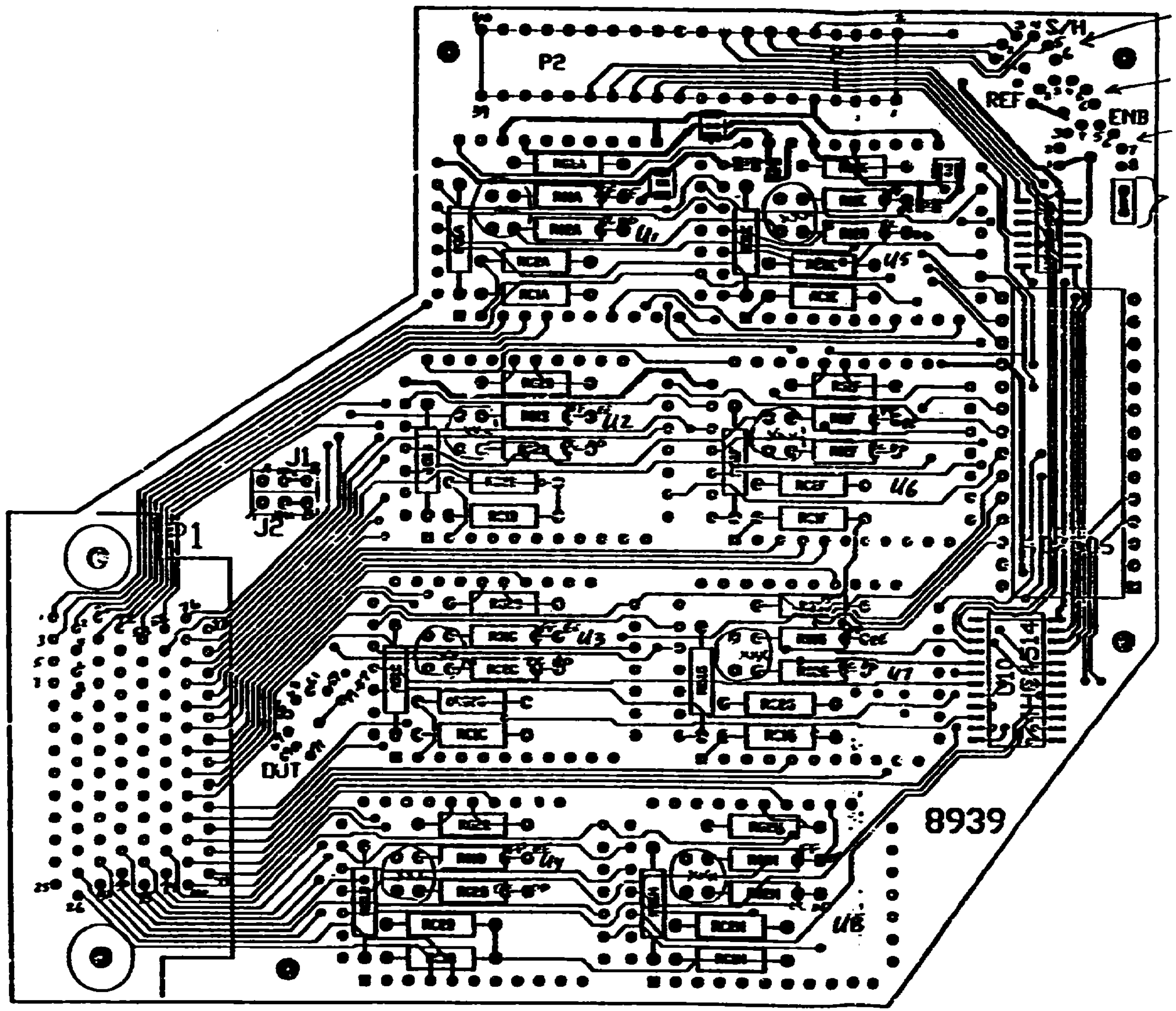
2.8.2 Analog Signal Conditioning Module

Each of the four analog signal conditioning modules are illustrated in Figure #30. The exact module geometry will be based on the interior dimensions and contour of the enhanced pelvis. Each module will be fabricated into a multilayer PCB, similar to the configuration illustrated in Figure #31, encased in a fiber resin or aluminum block, milled to provided side thickness on the order of 0.62 inches and a perimeter wall dimension of .125 inches. These individual modules will be stacked and interlocked filling the defined internal pelvis envelope.

The analog signal conditioning module schematic is illustrated via Schematic #2, and is referenced in the following paragraph. Each module consists of six dual channel hybrids (U1, U2, U3, U4, U5, U6), address decoding network (U8, U9) and an output multiplexer (U10). The module will support two connectors (P1, P2), where P2 is defined as the analog bus interconnecting all modules with a shared set of signals, typically provided by the processor subsystem I/O. Connector P1 is a high density ITT CANNON miniature connector, illustrated in Figure #32, providing all sensor inputs

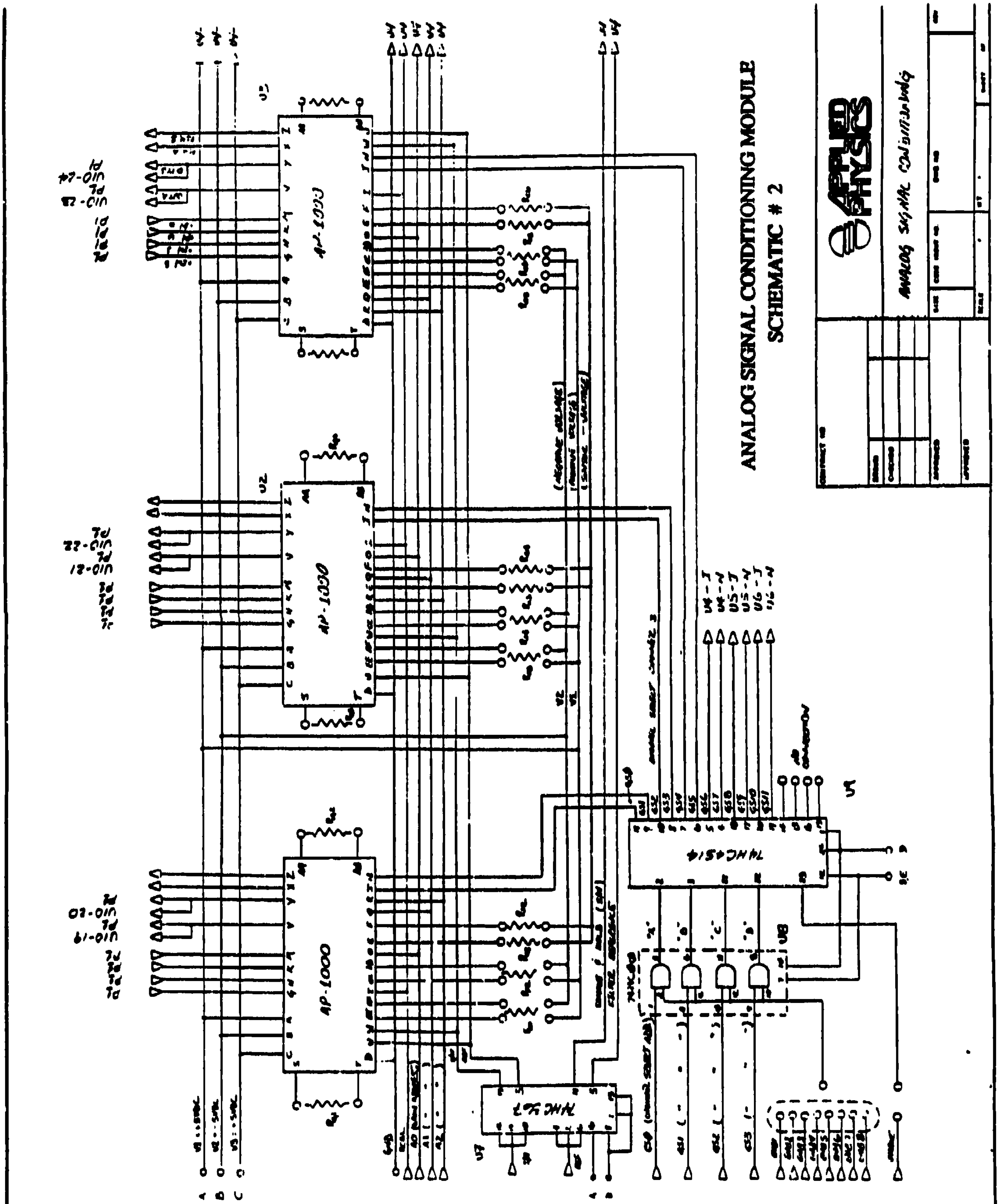


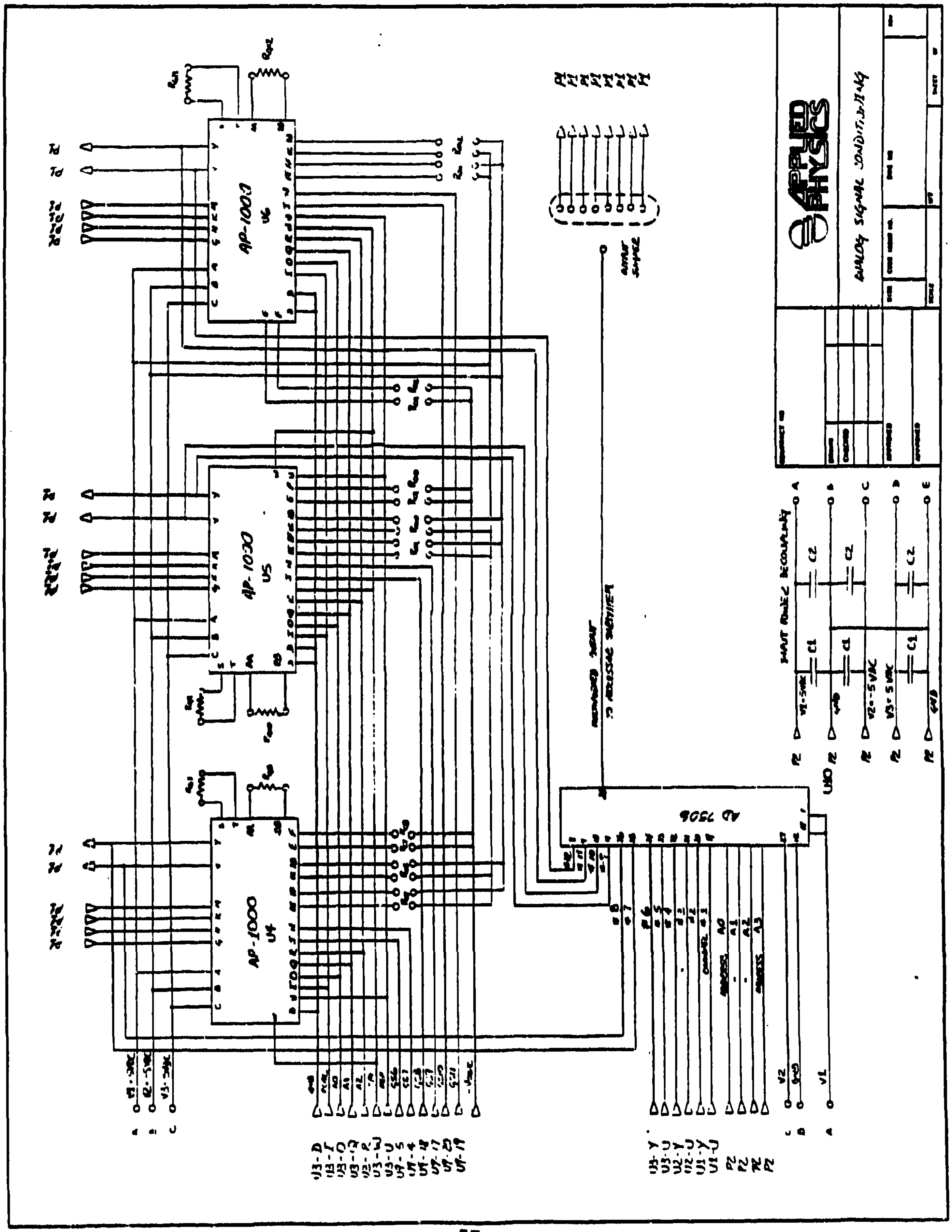
SIGNAL CONDITIONING MODULE
FIGURE 30



APPLIED.PCB Check Plot

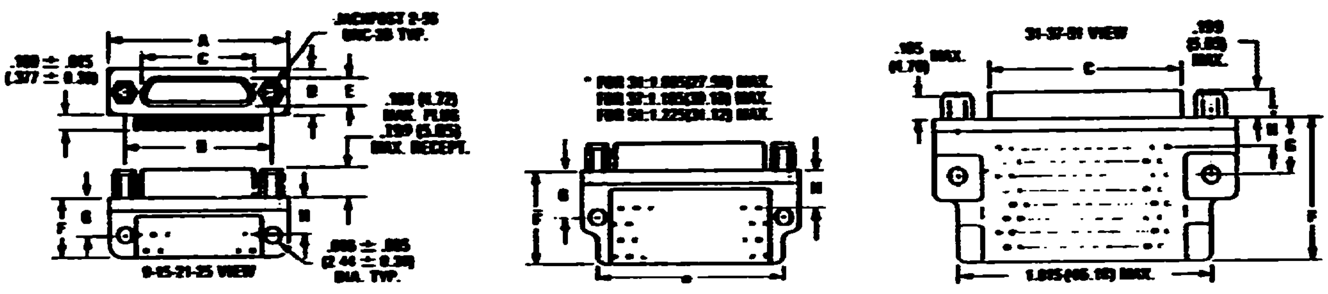
TYPICAL PCB CONFIGURATION
FIGURE 31


ANALOG SIGNAL CONDITIONING MODULE
SCHEMATIC # 2
APPLIED PHYSICS
AP-1000
74HC4514


APPLIED PHYSICS
ANALOG SIGNAL CONDITIONING
AP-1000
U4
AP-1000
U5
AP-1000
U6
AD 7506

CBR SERIES (90° NARROW PROFILE MOUNTING)

NOTE: Standard lead termination is #24 AWG, solid copper, solder or tin dipped.



Part Number By Shell Size	A Max.	B ±.005 (±0.13)	C Max.	D Max.	E Max.	F Max.	G ±.010 (±0.25)	H ±.010 (±0.25)
MDM-9PCBR*	.785(19.94)	.565(14.35)	.330(8.40)	.300(7.62)	.185(4.70)	.420(10.67)	.250(6.35)	.230(5.84)
MDM-9SCBR*	.785(19.94)	.565(14.35)	.400(10.20)	.300(7.62)	.253(6.43)	.420(10.67)	.250(6.35)	.230(5.84)
MDM-15PCBR*	.935(23.75)	.715(18.16)	.480(12.25)	.300(7.62)	.185(4.70)	.420(10.67)	.250(6.35)	.130(3.30)
MDM-15SCBR*	.935(23.75)	.715(18.16)	.550(14.00)	.300(7.62)	.253(6.43)	.420(10.67)	.250(6.35)	.130(3.30)
MDM-21PCBR*	1.085(27.56)	.865(21.97)	.630(16.10)	.300(7.62)	.185(4.70)	.420(10.67)	.250(6.35)	.130(3.30)
MDM-21SCBR*	1.085(27.56)	.865(21.97)	.700(17.83)	.300(7.62)	.253(6.43)	.420(10.67)	.250(6.35)	.130(3.30)
MDM-25PCBR*	1.185(30.10)	.965(24.51)	.730(18.60)	.300(7.62)	.185(4.70)	.420(10.67)	.250(6.35)	.130(3.30)
MDM-25SCBR*	1.185(30.10)	.965(24.51)	.800(20.32)	.300(7.62)	.253(6.43)	.420(10.67)	.250(6.35)	.130(3.30)
MDM-31PCBR*	1.335(33.91)	1.115(28.32)	.880(22.45)	.300(7.62)	.185(4.70)	.520(13.21)	.250(6.35)	.130(3.30)
MDM-31SCBR*	1.335(33.91)	1.115(28.32)	.950(24.10)	.300(7.62)	.253(6.43)	.520(13.21)	.250(6.35)	.130(3.30)
MDM-37PCBR*	1.485(37.72)	1.265(32.13)	1.030(26.20)	.300(7.62)	.185(4.70)	.520(13.21)	.250(6.35)	.130(3.30)
MDM-37SCBR*	1.485(37.72)	1.265(32.13)	1.100(27.94)	.300(7.62)	.253(6.43)	.520(13.21)	.250(6.35)	.130(3.30)
MDM-51PCBR*	1.435(36.45)	1.215(30.86)	.980(24.90)	.351(8.92)	.228(5.79)	.650(16.51)	.300(7.62)	.150(3.81)
MDM-51SCBR*	1.435(36.45)	1.215(30.86)	1.050(26.72)	.351(8.92)	.296(7.52)	.650(16.51)	.300(7.62)	.150(3.81)
MDM-100PCBR*	2.170(55.12)	1.800(45.72)	1.380(35.20)	.394(10.00)	.271(6.88)	1.000(25.40)	.400(10.16)	.200(5.08)
MDM-100SCBR*	2.170(55.12)	1.800(45.72)	1.515(38.48)	.394(10.00)	.339(8.60)	1.000(25.40)	.400(10.16)	.200(5.08)

ITT CANNON CONNECTOR

FIGURE 32

to the analog subsystem, and signal conditioned outputs to the processor. The P2 analog bus is defined in Table #4, while typical module I/O via P1 is defined in Table #5. The module supports the inclusion multiple external resistors integrated to each hybrid channel to provide voltage offset adjustment, external gain set, and a calibration resistor for piezoresistive transducer channels. Each hybrid is provided sampling (S/H) and filter reference pulse trains from the processor buffered via U7. The individual channel programming is accomplished by the processor controlled I/O manipulating the channel select and gain select input, defined as GS0, GS1, GS2, GS3 and A0, A1, A2, respectively. One of eight possible modules is defined via jumper block ENB, where ENB1 defines module one, ENB2 defines module two, etc., as indicated in Table #6. The individual selection of channel is accomplished via the channel select lines GS0-GS3, as indicated in Table #7. The gain is programmed into the selected channel and then defined by the gain address lines A0-A2 as defined in Table #8.

2.8.3 Analog Control and Conversion Module

The analog control and conversion module is illustrated in Figure #33. The module provides the multiplexed analog paths, secondary gain, automatic voltage offset adjustment and analog to digital conversion. Additionally, the module provides for multiplexor address generation and start of acquisition determination.

The detailed module schematic is shown in Schematic #3. The multiplexed output of each module is multiplexed via analog multiplexers (U1:U19). These signals are then provided to a secondary gain amplifier (U2; U20), and computer controlled automatic voltage offset adjustment circuits (U3, U4, U5, U6; U21, U22). The offset adjusted multiplexed signal is provided to the ADC-500 analog to digital converters (U7; U26). Each converter is high speed 12 bit resolution convert with a maximum conversion time of 500 ns. The converter provides both +/- 5 or +/- 10 voltage inputs with outputs available in two complement or bipolar. The recommended operation would focus on +/- 5 voltage operation in the bipolar mode. The 12 bit binary resultant output is interfaced to the computer STD bus via 8282 octal latches (U8, U9; U23, U24). The acquisition mode of DASS-II focuses on a interrupt structure, where an interrupt is generated at the desired sampling frequency. The CPU-I/O enables the input pulse to start the converters. The Schmidt trigger (U10; U25) pulse shapes the signal as required by the converters. The multiplex address generators (U12, U11, U13, U14, U15), consists of dual binary counters (U12, U11) initially set to zero at the start of each acquisition cycle (channel #1). At the end of each channel conversion cycle 500 nanosec, the end of conversion signal (EOC) increments the address count to the next channel. Following the maximum cycle of 48 channels, the counters are reset for the next acquisition cycle. The start of acquisition (enabling of the interrupt signal pulse train (INTRQ) is indicated when one or more channel exceed a predefined threshold.

Typical Analog Backplane P2:
Table # 4

P2-1	Enable Module 7
P2-2	Enable Module 8
P2-3	Mux Address A1
P2-4	Mux Address A0
P2-5	Mux Address A3
P2-6	Mux Address A2
P2-7	V1 + 5 VDC
P2-8	V3 + 5 VDC
P2-9	V2 - 5 VDC
P2-10	S/H 3 Buffered Sample & Hold Module 3
P2-11	Ground
P2-12	S/H 2
P2-13	Ground
P2-14	S/H 1
P2-15	A2 Gain Control
P2-16	S/H 4
P2-17	A1 Gain Control
P2-18	S/H 5
P2-19	A0 Gain Control
P2-20	S/H 6
P2-21	GS1 Gain Channel Select
P2-22	Ref 6 Filter Reference Module 6
P2-23	GS0 Gain Channel Select
P2-24	Ref 5
P2-25	GS3 Gain Channel Select
P2-26	Ref 4
P2-27	GS2 Gain Channel Select
P2-28	Ref 3
P2-29	Enable
P2-30	Ref 2
P2-31	RCAL Control
P2-32	Ref 1
P2-33	
P2-34	Enable Module 6
P2-35	
P2-36	Enable Module 5
P2-37	Enable Module 2
P2-38	Enable Module 4
P2-39	Enable Module 3
P2-40	Enable Module 1

Typical Analog Signal Conditioning Module I/O
MDM-100-095P -- P1 Connector

Pin #	Group Code	Description
1	M1-G1 BLACK	OUT A CHANNEL 1
2	M1-G1 BROWN	-INPUT CHANNEL 1
3	M1-G1 RED	OUT B CHANNEL 2
4	M1-G1 ORANGE	+INPUT CHANNEL 6
5	M1-G1 YELLOW	PCM OUT B CHANNEL 2
6	M1-G1 GREEN	OUT A CHANNEL 6
7	M1-G1 BLUE	PCM OUT A CHANNEL 1
8	M1-G1 PURPLE	
9	M1-G1 GREY	+INPUT CHANNEL 2
10	M1-G1 WHITE	-INPUT CHANNEL 2
11	M1-G1 WHITE/BLACK	-INPUT CHANNEL 7
12	M1-G1 WHITE/BROWN	+INPUT CHANNEL 10
13	M1-G1 WHITE/RED	
14	M1-G1 WHITE/ORANGE	OUTPUT CHANNEL 3
15	M1-G1 WHITE/YELLOW	
16	M1-G2 BLACK	
17	M1-G2 BROWN	+INPUT CHANNEL 5
18	M1-G2 RED	
19	M1-G2 ORANGE	
20	M1-G2 YELLOW	-INPUT CHANNEL 12
21	M1-G2 GREEN	+INPUT CHANNEL 3
22	M1-G2 BLUE	-INPUT CHANNEL 5
23	M1-G2 PURPLE	OUTPUT CHANNEL 5
24	M1-G2 GREY	-INPUT CHANNEL 8
25	M1-G2 WHITE	-INPUT CHANNEL 4
26	M1-G2 WHITE/BLACK	+INPUT CHANNEL 8
27	M1-G2 WHITE/BROWN	+INPUT CHANNEL 4
28	M1-G2 WHITE/RED	-INPUT CHANNEL 9
29	M1-G2 WHITE/ORANGE	-INPUT CHANNEL 4
30	M1-G2 WHITE/YELLOW	
31	M1-G3 BLACK	
32	M1-G3 BROWN	+INPUT CHANNEL 1
33	M1-G3 RED	OUTPUT CHANNEL 9
34	M1-G3 ORANGE	
35	M1-G3 YELLOW	OUTPUT CHANNEL 12
36	M1-G3 GREEN	
37	M1-G3 BLUE	-INPUT CHANNEL 10
38	M1-G3 PURPLE	+INPUT CHANNEL 11
39	M1-G3 GREY	OUTPUT CHANNEL 6
40	M1-G3 WHITE	+INPUT CHANNEL 9
41	M1-G3 WHITE/BLACK	
42	M1-G3 WHITE/BROWN	OUTPUT CHANNEL 4
43	M1-G3 WHITE/RED	
44	M1-G3 WHITE/ORANGE	OUTPUT CHANNEL 10
45	M1-G3 WHITE/YELLOW	OUTPUT CHANNEL 7
46	M1-G4 BLACK	OUTPUT CHANNEL 11
47	M1-G4 BROWN	
48	M1-G4 RED	
49	M1-G4 ORANGE	PCM B CHANNEL 8
50	M1-G4 YELLOW	OUT B CHANNEL 8
51	M1-G4 GREEN	-INPUT CHANNEL 11
52	M1-G4 BLUE	+INPUT CHANNEL 11

Module Selection
Table # 6

ENB1	ENB2	ENB3	ENB4	ENB5	ENB6	ENB7	ENB8	CHANNELS
0	0	0	0	0	0	0	0	DISABLE
1	0	0	0	0	0	0	0	1-12
0	1	0	0	0	0	0	0	13-24
0	0	1	0	0	0	0	0	25-36
0	0	0	1	0	0	0	0	37-48
0	0	0	0	1	0	0	0	49-60
0	0	0	0	0	1	0	0	61-72
0	0	0	0	0	0	1	0	73-84
0	0	0	0	0	0	0	1	85-96

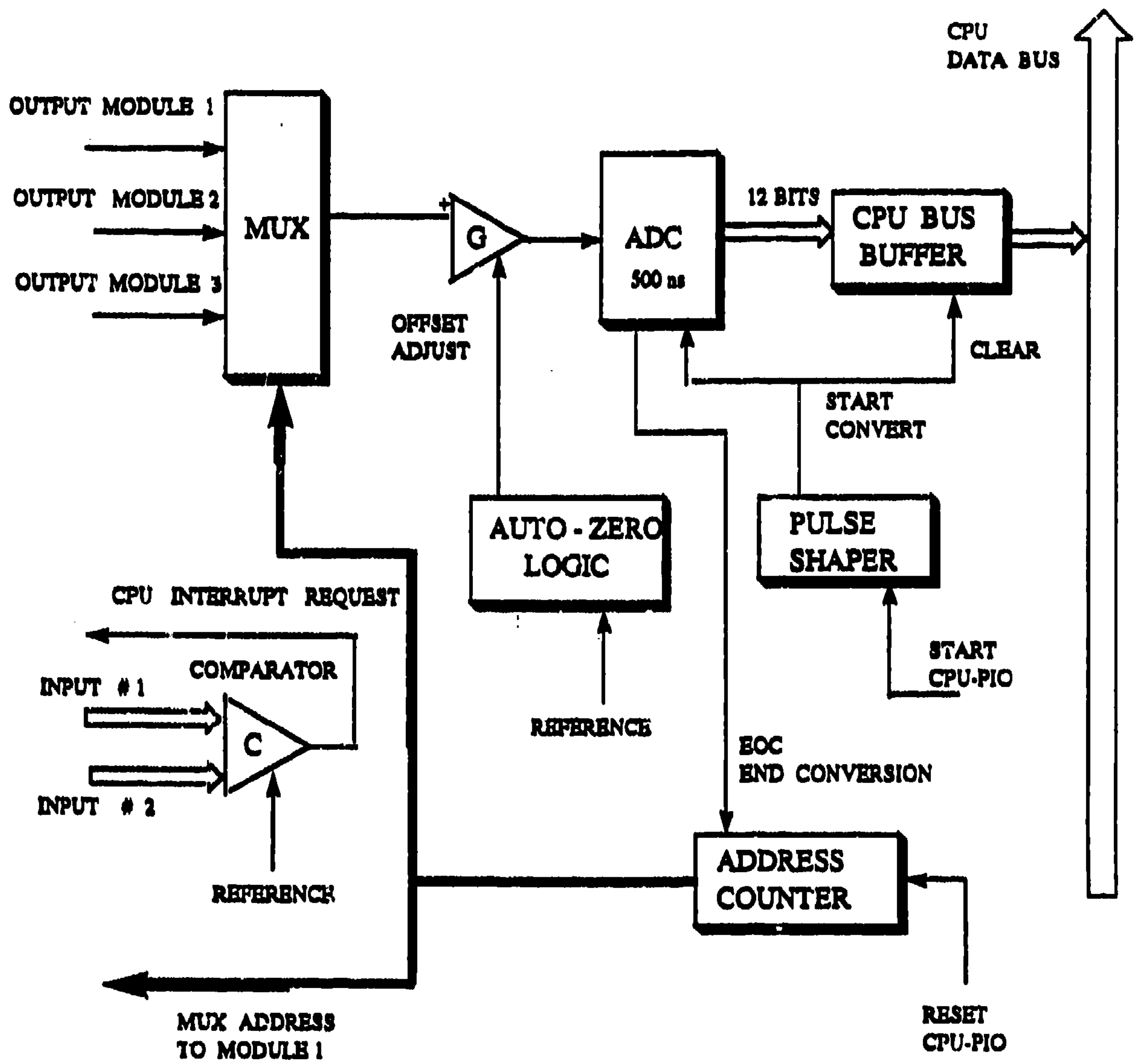
CHANNEL SELECTION
TABLE # 7

GS3	GS2	GS1	GS0	CHANNEL/MODULE
0	0	0	0	CHANNEL 1
0	0	0	1	CHANNEL 2
0	0	1	0	CHANNEL 3
0	0	1	1	CHANNEL 4
0	1	0	0	CHANNEL 5
0	1	0	1	CHANNEL 6
0	1	1	0	CHANNEL 7
0	1	1	1	CHANNEL 8
1	0	0	0	CHANNEL 9
1	0	0	1	CHANNEL 10
1	0	1	0	CHANNEL 11
1	0	1	1	CHANNEL 12

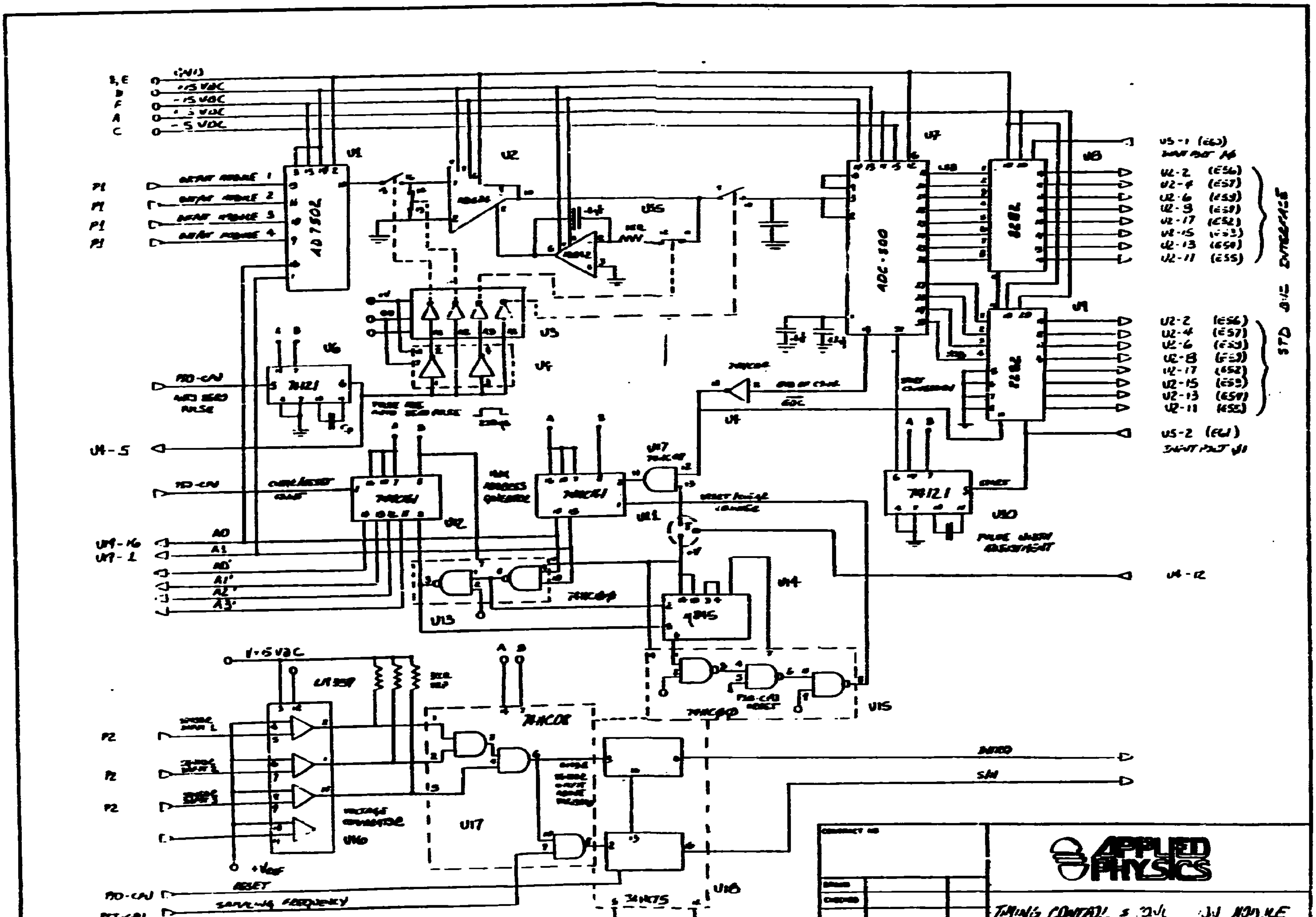
GAIN SELECT
FIGURE # 8

ENABLE	A2	A1	A0	GAIN
1	0	0	0	1
1	0	0	1	2
1	0	1	0	4
1	0	1	1	5
1	1	0	C	10
1	1	0	1	25
1	1	1	0	50
1	1	1	1	EXTERNAL R

TIMING, CONTROL, & CONVERSION MODULE

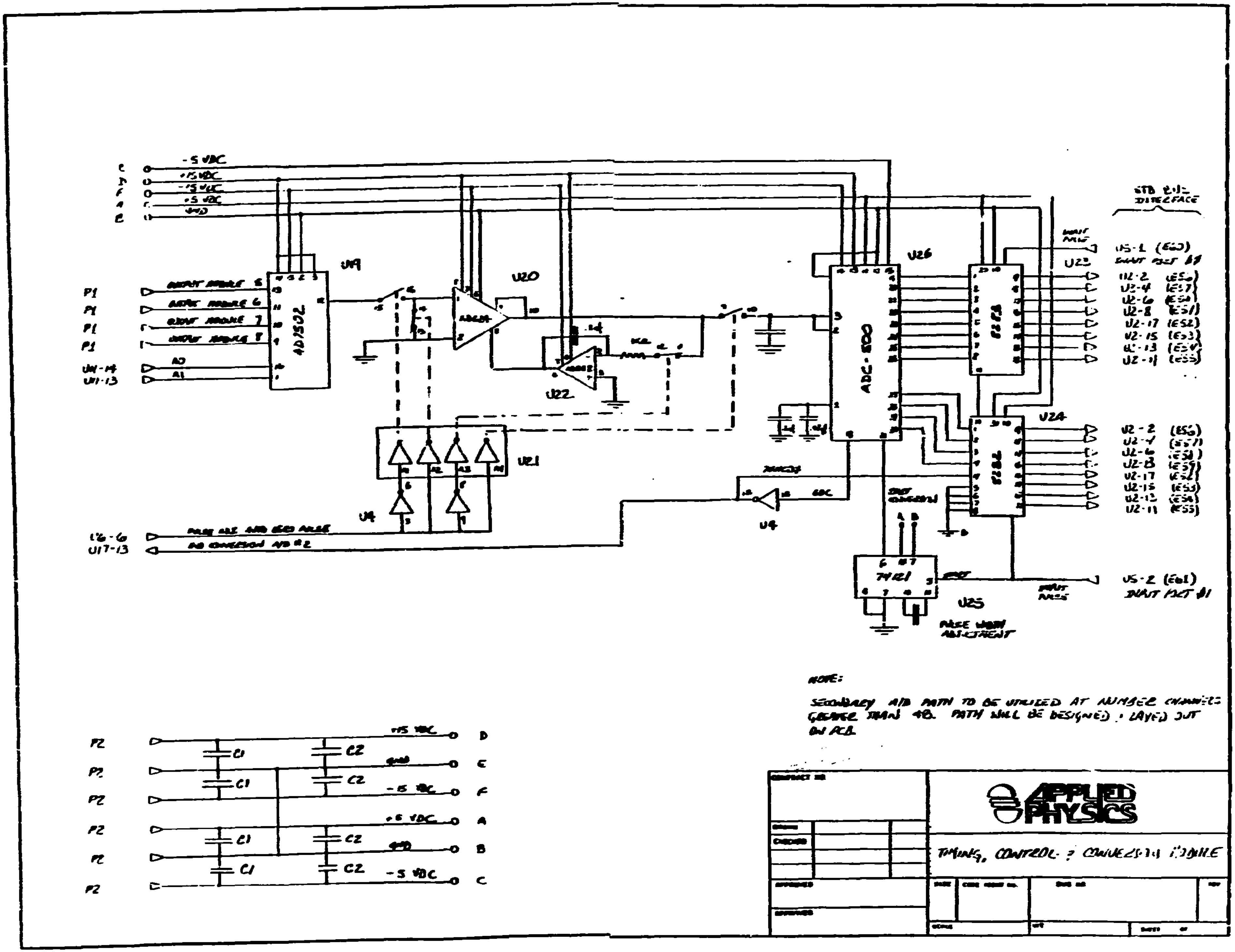


ANALOG CONVERSION MODULE
FIGURE 33



ANALOG CONTROL & CONVERSION MODULE

SCHEMATIC #3


STD BUS INTERFACE
U19
4D1502
U20
U21
U22
U26
ADC-800
U24
U25
74121
PULSE WIDTH ADJUSTMENT
NOTE:
SECONDARY A/D PATH TO BE UTILIZED AT NUMBER CHANNELS GREATER THAN 48. PATH WILL BE DESIGNED & LAYED OUT ON PCB.
-5 VDC
+15 VDC
-15 VDC
+5 VDC
GND
A0
A1
C1
C2
APPLIED PHYSICS
TIMING, CONTROL & CONVERSION MODULE

Comparator (U16) compares three transducer output to a fixed voltage re' rence (+Vref). Once exceeded, the start signal is latched via U17, U18 er ling the acquisition cycling, until reset by the processor.

It is not completely clear whether this module will be housed within the pelvis or within the chest cavity along with the processor. The component layout has been confirmed to fit onto a module in size corresponding to the pelvis geometry, however, the interface to the computer bus warrants the module to be in the proximity of processor bus. Typically, extension of the computer bus via a cable harness tends to increase noise on the bus producing many undesired timing and communications problems.

2.9 DASS-II Processor Subsystem

2.9.1 Requirements

The DASS-II processor requirements are functionally related to processor throughput, memory addressability and access speed. The processor must be able to acquire and control a maximum of 48 analog channels sampled at a maximum of 10000 Hz for several seconds providing direct storage of this experiment data, along with calibration and status information. In addition, the processor maintains communications with the user interface (laptop PC) for control and data transfer.

The primary measure of processor performance is throughput, commonly expressed as millions of operations per second or millions of instructions per second. For this analysis, throughput is slightly redefined as the processor's capability to perform a software controlled acquisition of 48 channels, specified as a function of sampling frequency. The throughput can be specified as follows and is illustrated in Figure #34.

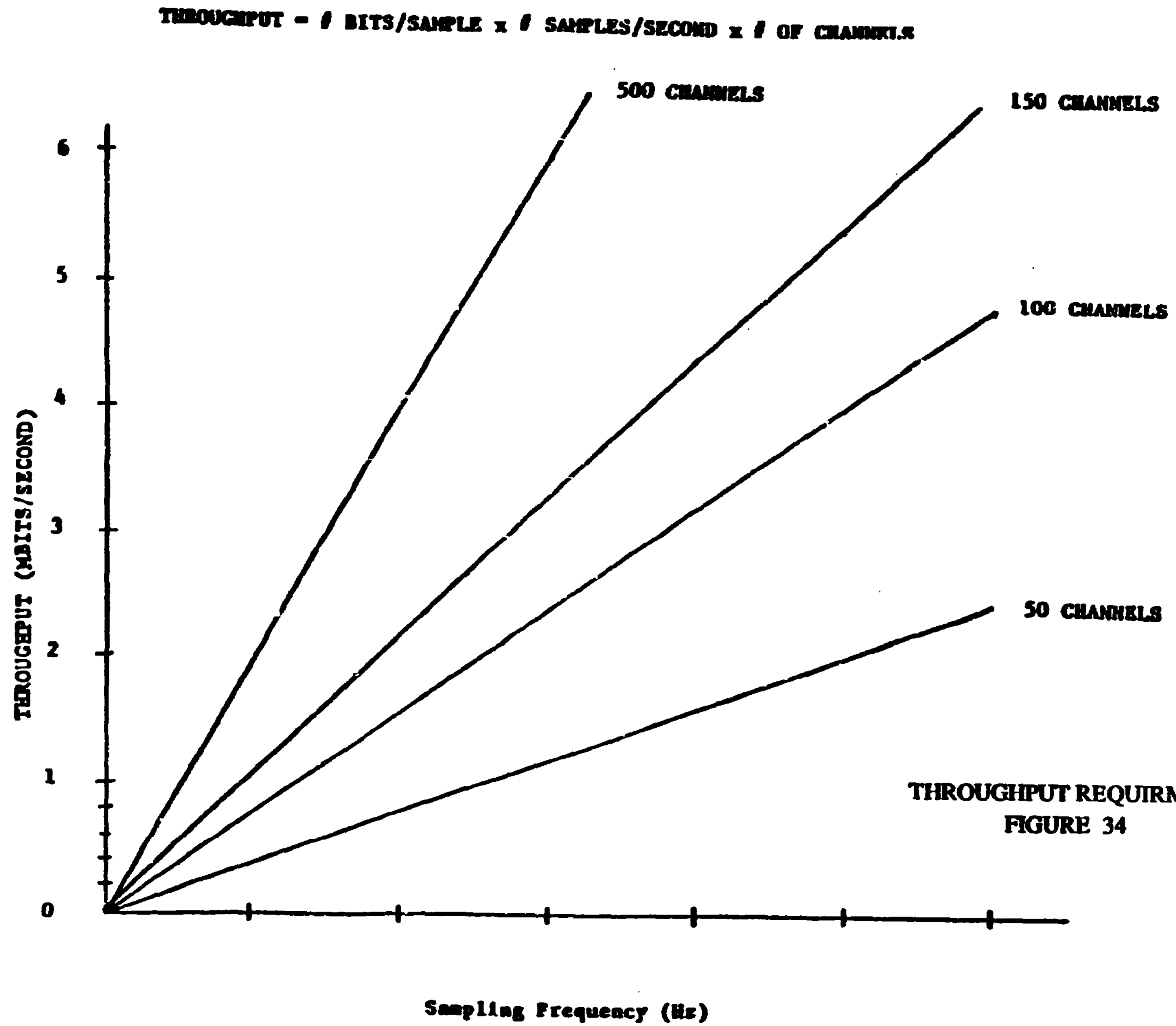
$$tp = N*C*fs$$

where:

N = number of bits/channel
C = number of channels
fs = sampling frequency

Since processors typically handle data in bytes (8 bits) or 16 bit words, the throughput is better represented in these terms. Consequently, 480K 16 bit data words/second or 960K bytes/sec represent the minimum system throughput requirement. At a sampling frequency of 10000 Hz, the maximum acquisition time is 100 microseconds. Applied Physics has tested a mock up acquisition loop on a 8088 at 8 MHz, indicating approximately 200 microseconds required to perform an acquisition of 48 channels, assuming all instructions necessary to control the an· ·g subsystem as designed. Clearly attaining the acquisition speed necess· is easily attained utilizing the newer series processors such as the 80286, or 80386 operating at 20 or 25 MHz.

The system memory requirements for the DASS-II ar· defined as a function of A/D converter resolution, sampling rate, nun · of channels, and experiment time. The relationship can be simply outl··ed as follows:



THROUGHPUT REQUIRMENTS
FIGURE 34

Mreg = N*C*fs*texp

where: N = number bytes/channel
C = number of channels
fs = sampling frequency
texp = experiment time

Again, considering 48 channels at 16 bits/channel (12 bit converter output, 4 MSB bits each equal zero), sampled at 10KHz, the memory requirement becomes 960 Kbytes per second.

The system will support a bus structure consistent with addressing, communications and data transfer requirements. Communications must exist between the user PC and the DASS-II processor, defining interactive user/system operation. The processor/memory implementation must minimize power utilization (since the system is battery powered), and provide nonvolatile memory and data integrity for a minimum of 2 hours. Finally, the system size and packaging must be minimized to mount the system within the manikin.

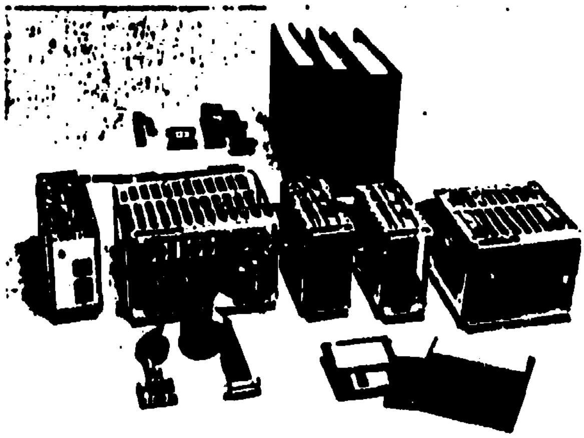
2.9.2 Processor Module

It is recommended that the processor subsystem be based on a CMOS 80286 single board computer, implemented on a STD bus configuration. The small size of the STD configuration 7.75" * 5.75" PCB makes it highly desirable in comparison to the alternative VME or MULTI.BUS configurations. Applied Physics has reviewed several commercial vendor configurations detailed in Figures #35, 36. The specific requirements of this application will require 25 MHz operation, minimum ZMbytes of memory, 2 programmable interval times, sampling frequency, and filter reference and sufficient parallel input/output to be included on the single module.

Applied Physics proposes the utilization of a Computer Dynamic SBC-AT, as illustrated in Figure #37. The features of the processor module are summarized as follows:

* 100% IBM compatible (hardware, software, BIOS)
* 80C286 CPU at 20 or 25 MHZ operation
* 1M, 2M or 4M DRAM memory options
* 256K EPROM (DASS-II operating software)
* Two RS232 communication ports
* Parallel printer port (8 parallel I/O lines)
* SBX extension
* Single 5NDC operation
* Dual interrupt controllers
* 3 Programmable interval timers

In order to provide additional parallel I/O capability, the processor STD module will be interfaced with an SBX module as illustrated in Figure #38. The system will additionally use a CDX-P48 manufactured by Computer Dynamics. The CDX-P48 is a general purpose, 48 line parallel input/output



SYSTEM 2 MODEL 60 INDUSTRIAL COMPUTERS

System 2 Model 60 is a rugged 80C286-based PC/XT®-compatible industrial computer that provides performance comparable to or exceeding that of many 80386-based computer systems. The reliability and modularity of Model 60 make it ideal for embedding into high-performance control systems that must operate in harsh environments.

Based on Pro-Log's 7892 System 2 Model 60 80C286 CPU Card, Model 60 supports the use of additional Pro-Log multimaster CPU cards to further increase system throughput. With the addition of peripheral and industrial I/O interfaces, the system can be customized for robotics, machine control, data acquisition, test and measurement, and other industrial or data processing applications.

Because Model 60 is PC/XT-compatible and contains Microsoft's® MS-DOS 3.3® operating system in a semiconductor (ROM) disk, you can use a wide range of familiar software tools and applications programs for system development and integration. The modular and open architecture of the system allows it to be expanded and upgraded in the future to meet new requirements.

FEATURES

- Provides high-performance 80C286 computer in 12.5 MHz and 25 MHz versions
- Norton SI rating of 28.8 (for 25 MHz version)
- Supports multimaster (multiple-processor) designs
- ROM-based MS-DOS 3.3 Operating System
- 640K bytes of DRAM system memory
- BIOS and BIOS extensions are transferred to DRAM on boot-up for fast execution
- Optional math coprocessor
- IBM PC/XT-compatible RS-232 port, counter/timer, and interrupt controller
- 0° to 65°C operating temperature range
- Withstands up to 40g shock and 5g vibration
- Core system MTBF greater than 6 years
- Five-year parts and labor warranty

FUNCTIONAL CAPABILITY

The high performance of the System 2 Model 60 Industrial Computer allows it to perform a wide variety of complex and extensive control functions. Even as a single CPU card system, the Model 60 executes DOS programs at more than three times the speed of an 8.0 MHz PC/AT®. For even higher real-time performance, Model 60 can be expanded to include additional multimaster processors.

Model 60 Core System

The core system consists of the 7892 System 2 Model 60 80C286 CPU Card and the 7171A System 2 Multimaster Support Card installed in a BX-Series card rack.

The 7892 System 2 Model 60 80C286 CPU cards include the 80C286 microprocessor and its associated support circuitry, the multimaster bus interface, PC/XT-compatible BIOS PROM and peripheral devices, a full 640 KBytes of DRAM system memory, shadow RAM operation of the BIOS and BIOS extensions (where code in PROM is moved into on-card DRAM for faster execution), and a socket for an optional 80287-compatible numeric coprocessor. The standard Model 60 CPU card is the 7892-02, which includes a 25 MHz 80C286. The 7892-03 is a lower-cost version with a 12.5 MHz 80C286.

The IIT 2C87 numeric coprocessor is used to provide 80287 functions. The 2C87 is fully software-compatible with the 80287, performs calculations at least three times faster than the 80287, uses 40% less power than the 80287, and operates over the full 0 to 65°C temperature range.

The 7171A System 2 Multimaster Support Card includes a wide range of facilities to support the Model 60 CPU card, including a ROM disk drive containing the MS-DOS operating system and utilities, bus termination circuitry, a precision reset circuit, power indicator LEDs, global RAM used for communications between multimaster CPU cards, and the multimaster clocking signal used for bus arbitration.

VENDOR CPU CONFIGURATION 1

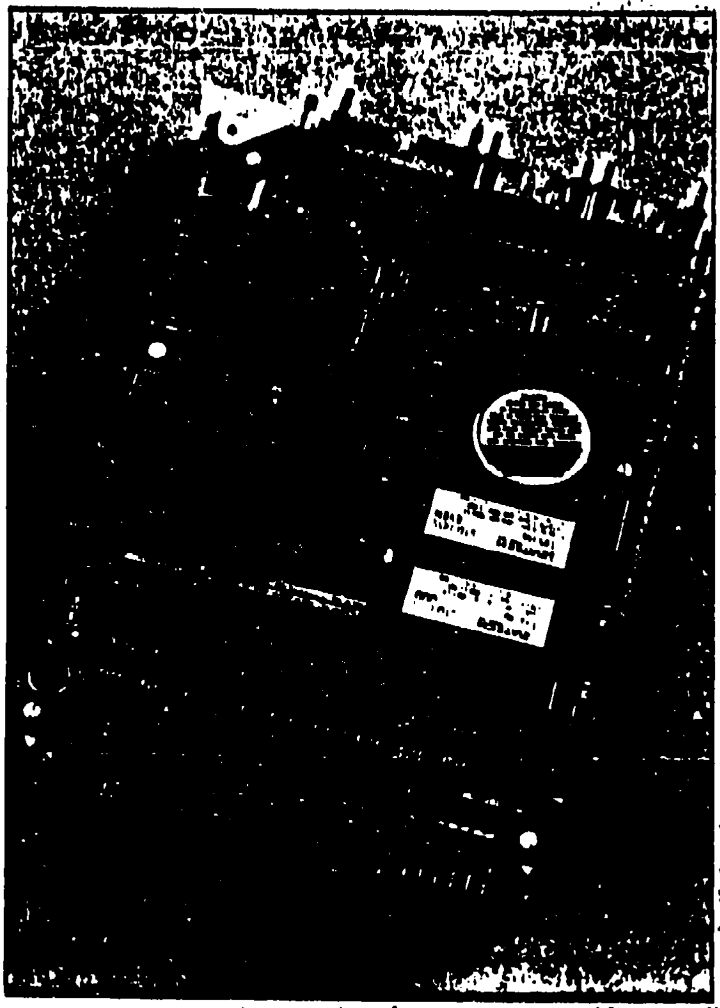
FIGURE 35

ZIATECH CORPORATION

CONTROL POINT

Test and Control Product News from Ziatech Corporation Winter, 1989-1990

NEW 386SX COMPUTER SUPERCHARGES STD BUS



Ziatech's ZT 8910 Industrial Board Computer

A new high-performance STD Bus computer from Ziatech provides 386SX performance, 100% IBM AT software compatibility, and over 4 Mbytes of on-board memory capacity.

The ZT 8910 is designed for industrial applications that previously required the use of a larger format and more expensive solution such as VME or MULTIBUS.

(Continued on page 2)

STD 32

Ziatech introduces new 32-bit STD bus

To provide STD Bus users with a growth path to 32-bit performance and to fill the need for a small format, 32-bit industrial computer, Ziatech has developed a new bus standard called STD 32.

COMPATIBLE WITH STD BUS

STD 32 incorporates an 8-, 16-, or 32-bit data path over the bus,

(Continued on page 3)

INSIDE

ZIATECH CORPORATION

VENDOR CPU CONFIGURATION 2

FIGURE 36

COMPUTER DYNAMICS, INC.
107 S. Main St.   Greer, SC 29650
(803) 877-8700

SBC-AT
100% PC/AT COMPATIBLE SINGLE BOARD COMPUTER

Description

The SBC-AT offers all the functions of the IBM PC/AT. We have reduced the high-powered PC/AT to a single 7.75 x 5.75 inch board while improving reliability. The SBC-AT is 100% PC/AT compatible at all levels: hardware, BIOS, and operating system. If a program runs on your AT, it will run on a similarly equipped SBC-AT-- GUARANTEED! The SBC-AT offers all the functions necessary to run MS-DOS or UNIX. No additional boards are needed. Simply add a power supply, drives, monitor and keyboard.

The SBC-AT is available with several display options. The -VGA version gives you the highest resolution with colors from a 256k palette. All versions are downward compatible and designed for the industrial environment. The -EGA version offers high resolution graphics with up to 64 colors and controls high resolution and color flat panel displays. The -CGA version generates simple color graphics or well formed text and controls up to 640 x 400 flat panel displays.

The SBC-AT includes a licensed off-the-shelf BIOS to run MS-DOS. DOS can boot and run from a floppy or hard disk drive. You can even boot and run MS-DOS from on-board ROM disk. This allows you to have a totally diskless target system. Additionally, you can use our "ROM Tools" and "DOS Emulation" to boot and run your target code without MS-DOS or its royalties.

Features

- 100% IBM PC/AT hardware, software and BIOS compatible
  - 80C286 CPU at 12.5, 16, 20, or 25 MHz
  - 512k, 1M, 2M or 4M bytes of DRAM
  - 256k EPROM socket (includes BIOS)
  - Keyboard and speaker interface
  - Two RS-232 COM ports
  - Parallel printer port (bi-directional)
  - Battery-backed real time clock w/RAM
  - Floppy disk controller (two 3.5" or 5.25" drives)
  - IDE/AT embedded controller disk interface
  - Your choice: VGA, EGA or CGA/monochrome display controllers for CRTs, LCD, EL, Plasma and vacuum fluorescent displays
- Second battery-backed RAM/ROM socket for up to 256k
- SBX expansion socket
- PC/AT expansion connector
- 0-70° C operation

Specifications

PC/AT Compatible Processor System

• CPU	80C286 CMOS 16-bit CPU
• Speed	12.5, 16, 20, or 25 MHz w/ software selection to 8 MHz
• Math	80287 socket provided
• DRAM	512k, 1M, 2M and 4M with parity and no waitstates
• RAM expansion	Extended memory (UNIX compatible); expanded memory EMS4.0/LIM (optional)
• BIOS EPROM	One 256k which may be shadowed to RAM for faster 16-bit full-speed execution. May be ROM disk
• BIOS	Standard Quadtel BIOS included (cleanroom-generated)
• RAM/ROM DISK	One 32 - 256k battery-backed additional socket
• DMA	Two 8237 DMA controllers
• Interrupt	Two 8259 interrupt controllers
• Counter/timer	8254 with 3 counter/timers

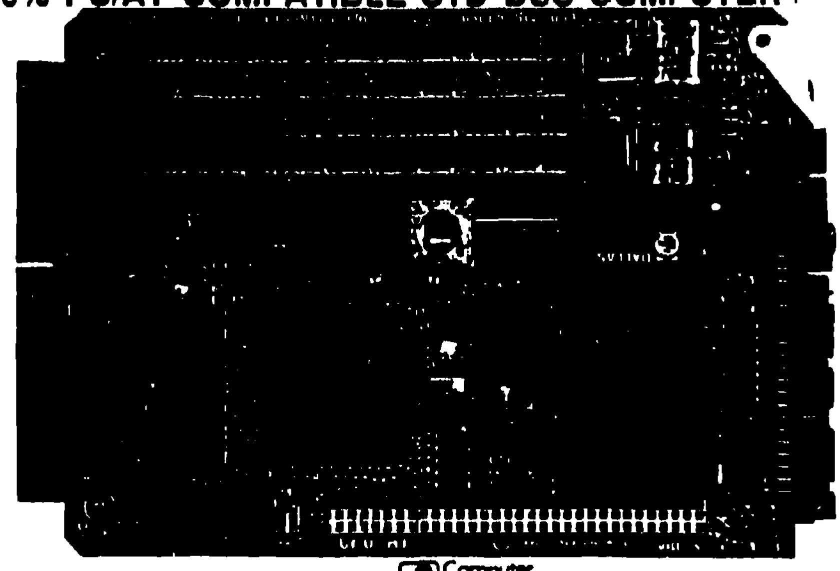
PC/AT Compatible I/O

• Keyboard	PC/AT compatible keyboard interface; keyboard is not required to boot DOS
• COM ports	Two standard 8250 ports with PC/AT pinouts
• Printer	Parallel printer port w/ full readback; may also be used as industrial parallel I/O
• RT clock	Battery-backed real-time clock w/ PC/AT battery-backed RAM
• Speaker	4-16 ohm speaker or piezo driver

Industrial Functions

• Watch-dog timer	Software enable/disable
• Parallel I/O	The parallel printer port may also be used as 8 outputs with readback, 4 programmable input/outputs, 4 inputs, and 1 input with interrupt
• PC expansion	Header connectors for PC/AT/XT compatible bus
• SBX expansion	SBX socket w/interrupts (Intel iSBX standard)
• Electrical	+5V 5%, <1 A
• Temperature	0-70° C
• Mechanical	5.75" x 7.75" x 0.65" (4 mounting slots)

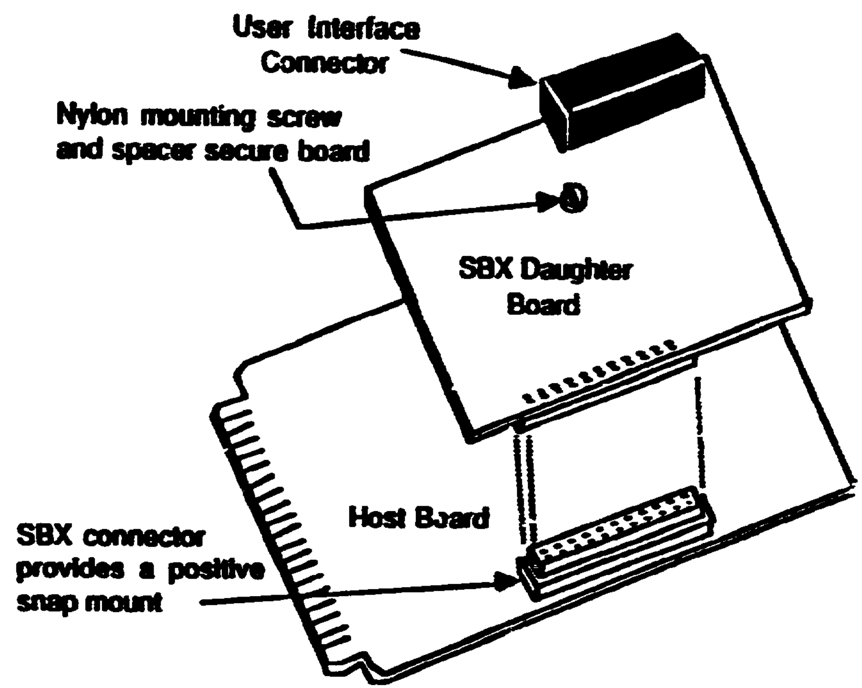
100% PC/AT COMPATIBLE STD BUS COMPUTER



Computer DYNAMICS

COMPUTER DYNAMICS SBC-AT

FIGURE 37



SBX Mounting Technique

SBX MODULE
FIGURE 38

board design on a SBX platform. This product contains two Intel 8255 I/O devices which allow flexible programmability for control of the analog subsystem.

2.9.3 DASS-II Storage Memory

As indicated, the DASS-II must support a minimum storage capability of 960K bytes per second. As was previously agreed, 2 Mbytes easily satisfies the DASS-II requirements at this time and can easily be expanded in the future. As indicated, the proposed SBC-AT processor module satisfies the memory requirements via the on-board DRAM. Because of low power consumption of this module, the processor subsystem of DASS-II can easily be powered for the 2 required hours, prior to data offload or transfer to the laptop support computer.

As a preferred alternative, Applied Physics proposes the utilization of a credit card memory device as illustrated in Figure #39. These products provide several problems that need to be addressed prior to commitment on being able to utilize them on this design. First, these devices must be of sufficient speed (memory access time) to enable real time data storage by the processor. Secondly, these memory devices must be interfaced with the DASS-II STD computer bus. Thirdly, to be able to use these credit card memories, the supporting IBM must also be able to read/write onto these modules. This involves development of a IBM bus interface module and DOS software driver. These tasks may represent a increased cost to the contract, since they are beyond the original scope and will require additional evaluation during phase II. Clearly, this alternative is highly desirable, providing easy data transfer even if the manikin processor system is destroyed or damaged.

Should these memory devices be used to slow for real time access, they can alternatively be used as an manikin internal data transfer device. For example, post experiment data is offloaded from the DRAM to the memory card, after which time the manikin is shut down. Because of the extensive time from post experiment to data offload complete, significant battery power can be saved utilizing this alternative.

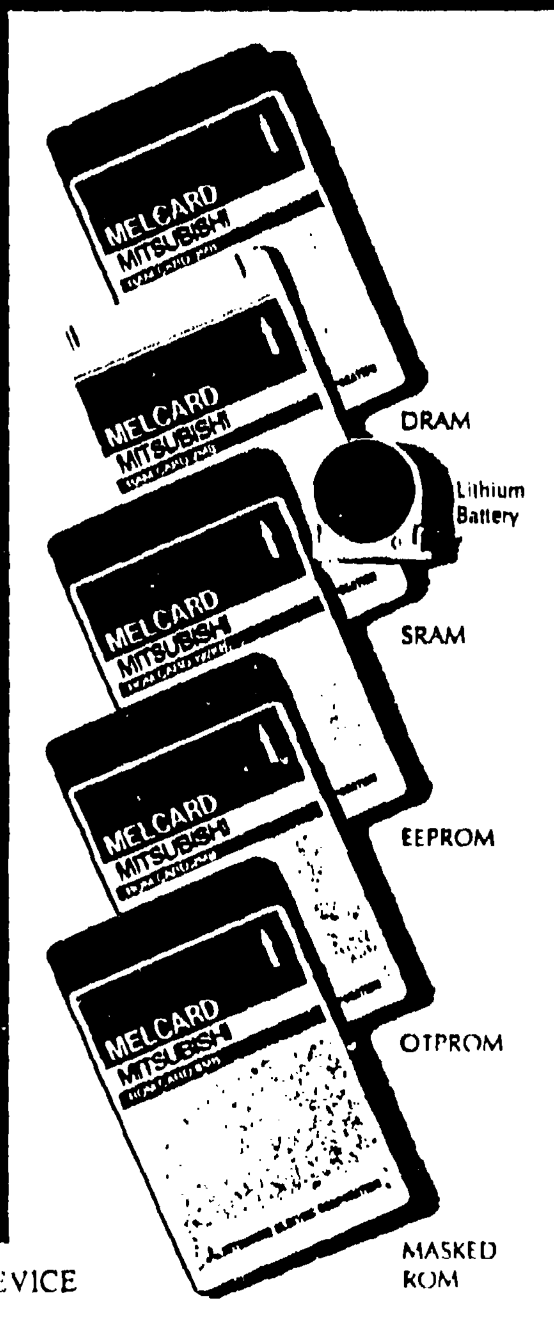
2.10 DASS-II Operating Software

The DASS operating software defines the detailed functioning and operation of the microprocessor-based system. The system software is written in assembly language, a source code language employing mnemomic instructions, translated into machine (binary language) program by substituting operation codes and addresses. The primary operating software is permanently stored in ROM. The DASS operating software defines and sequences the system functions of acquisition, calibration, diagnostics, communications and control of all logic and analog circuits. The software is divided into the following modular subroutines or function units:

* System Monitor
* Preflight
* Calibration
* Communications

Memory Cards

Your Creative Tools For Success



CREDIT CARD MEMORY DEVICE
FIGURE 39

MITSUBISHI ELECTRONICS

SPECIFICATION	PREPARED	M. Kimura T. Shindo	REV			
	APPROVE	H. Nishiyama				

SPECIFICATION of IC CARD

1. TYPE NO. MF13M1-M1CAPXX
(The xx in type code is a two-digit numerical or alphabetical code assigned by Mitsubishi to identify the customer's specification such as enclosure panel design.)

2. APPLICATION MEMORY CARD

3. CONSTRUCTION DRAM CARD (TWO-PIECE CONNECTOR)

4. FUNCTION 3M BYTE DRAM
(16 BIT DATA-BUS WIDTH)

5. OUTLINE 54mmW×85.6mmL×3.4mmT

* Acquisition
* Data Transfer

These subroutines constitute the DASS-II operating system and will be initiated through communication with the user PC interface establishing an optimized operating scenario.

2.10.1 DASS-II IBM Support Computer Communications

Communications between the DASS-II microprocessor and the support PC will be achieved via a series of transmitted ASCII command codes. Typical operation of the communications interface can be outlined as follows:

i) The user selects an option from the IBM main menu or submenu provided to the user on the IBM.

ii) Based on the option selected, a unique ASCII character command code is sent to the DASS-II via the serial RS232 port.

iii) The DASS-II transmits to the IBM on the RS232 a unique function acknowledgement character indicating command received and acknowledged.

iv) The DASS-II then performs a specified option or subroutine and transmits a response ASCII character code, if necessary. For example, the diagnostics option can transmit test pass/fail status to the IBM.

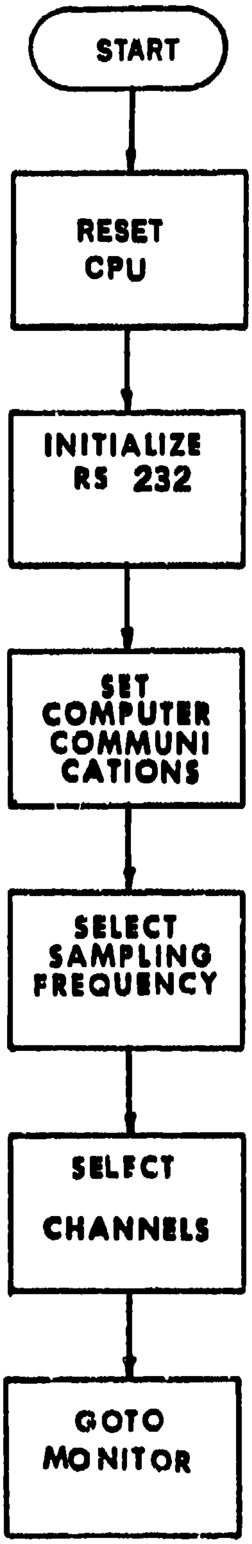
v) The DASS-II upon completion of the specified task, transmits a function complete ASCII code to the IBM.

vi) The IBM will then return the user to the main or submenu for the user to perform the next function.

vii) Options involving data offload such as CAL data transfer or all data transfer will utilize the RS232 port to offload data. All data will be transferred as ASCII characters with unique start/stop control characters used to stop transmission.

2.10.2 Preflight/Initialization

The "Preflight/Initialization" routine will automatically execute at power up or system reset, initializing and specifying the variable system characteristics. The initialization routine, illustrated in Figure #40 will initialize all the parallel I/O ports on the CPU module and the SBX module. The system will support a default configuration such that the routine sets the default channel gains and sampling frequency as defined in ROM based system tables. Gain will be set by outputting via the SBX, the channel select and gain select address to each of the hybrids as previously defined. The initialization routine finally checks all counters and latches to be used by the system. Once completed, the routine exits to the system monitor.



INITIALIZATION
FIGURE 40

2.10.3 System Monitor

The system monitor software as illustrated in Figure #41 will maintain communications with the user support IBM computer and processor and decode the command strings as detailed above. Once command codes have been decoded, DASS-II operation is directed to the subroutine performing the desired operation.

2.10.4 Acquisition

The optimized acquisition routine is illustrated in Figure #42 and is divided into two parts, a preinterrupt setup portion, updating the necessary counters and registers, and a interrupt response section performing the actual data acquisition for each interrupt. In the preinterrupt phase, the routine will verify the number of active channels, update the time markers, memory pointers, and elapsed time counter. Upon the occurrence of an interrupt pulse, the acquisition algorithm will initiate an A/D conversion and enter a 500 nanosecond converting wait loop. The routine will input 4 bytes of data from the dual 12 bit A/D paths and store the raw data directly into memory. Subsequently, the routine will update the memory pointer and check whether all channels have been collected in this cycle. If not, conversion is initiated on the next set of channels. If all channels have been acquired, acquisition will terminate with an end of cycle "*" character stored into memory and reset all counters, pointers and latches reset. The routine then returns to the preinterrupt section awaiting the next interrupt cycle. Once maximum elapsed time or available memory has been expended, the system will manage the power assembly controller and shut down all unnecessary power except memory backup.

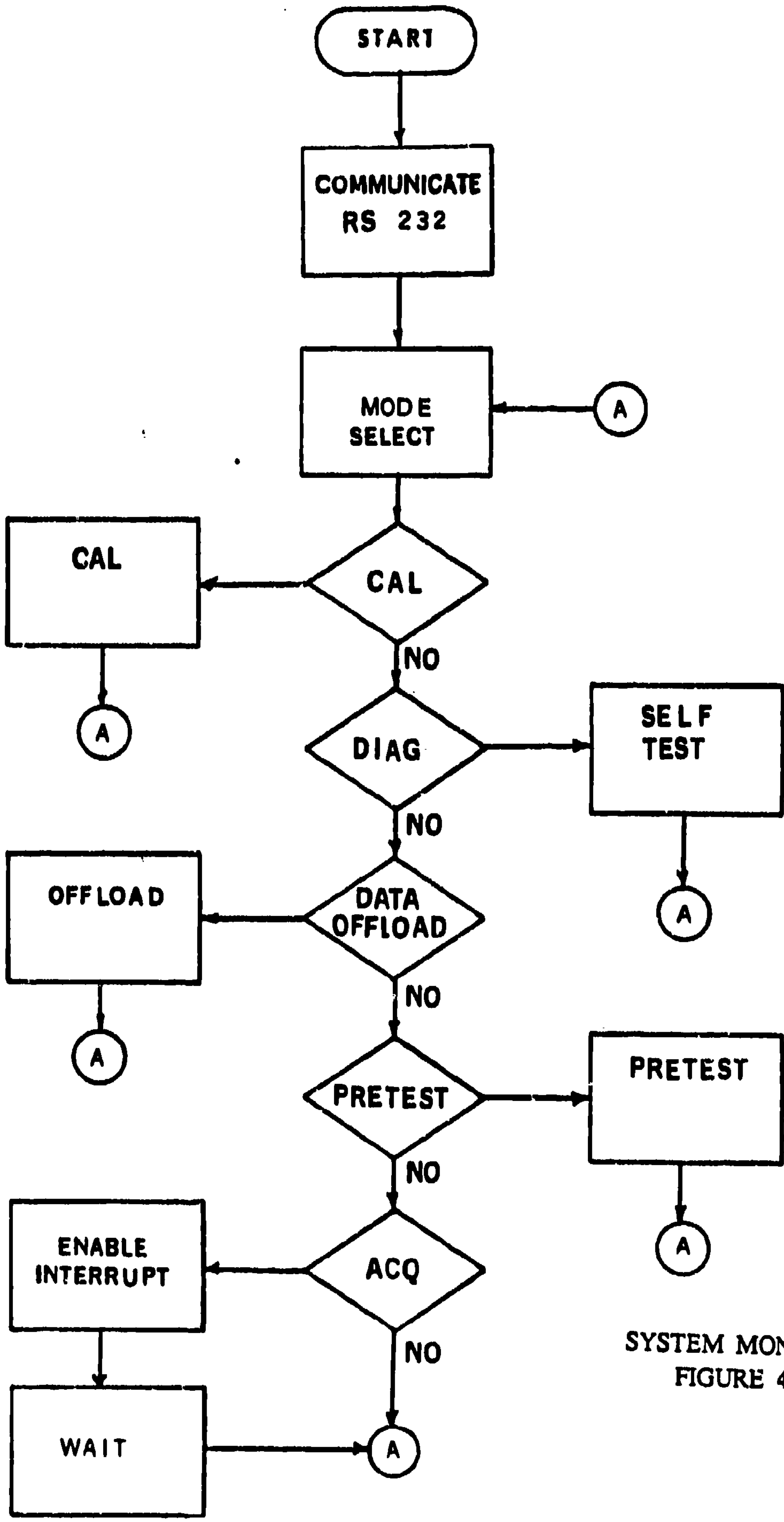
If the credit card memories are utilized in the backup module (not as a real time storage source), data will be transferred from the processor RAM to credit card memory prior to shut down.

2.10.5 Data Transfer

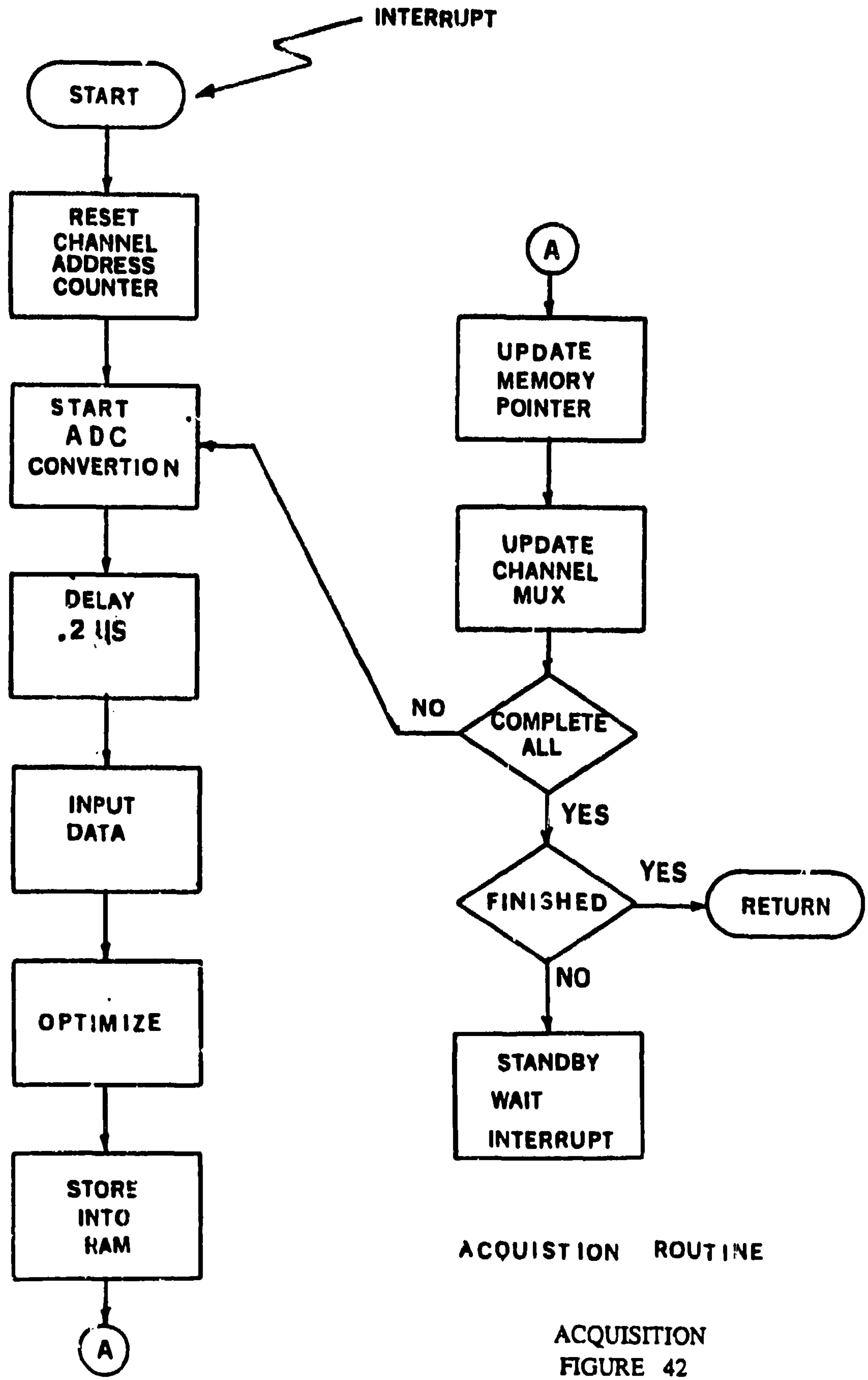
The data offload or transfer routine is illustrated in Figure #43. This routine will basically offload sequentially all data stored within the DASS-II memory. Prior to transfer via the RS232, the A/D data will be converted from binary to ASCII. Once all data has been transferred, a unique end of file and end of transmission character will be sent. Should the credit card memories be utilized, this routine will be replaced with memory to memory transfer routine with the conversion to ASCII performed either on the DASS-II or IBM. As before, upon completion, the subroutine will return to the system monitor.

2.10.6 Calibration

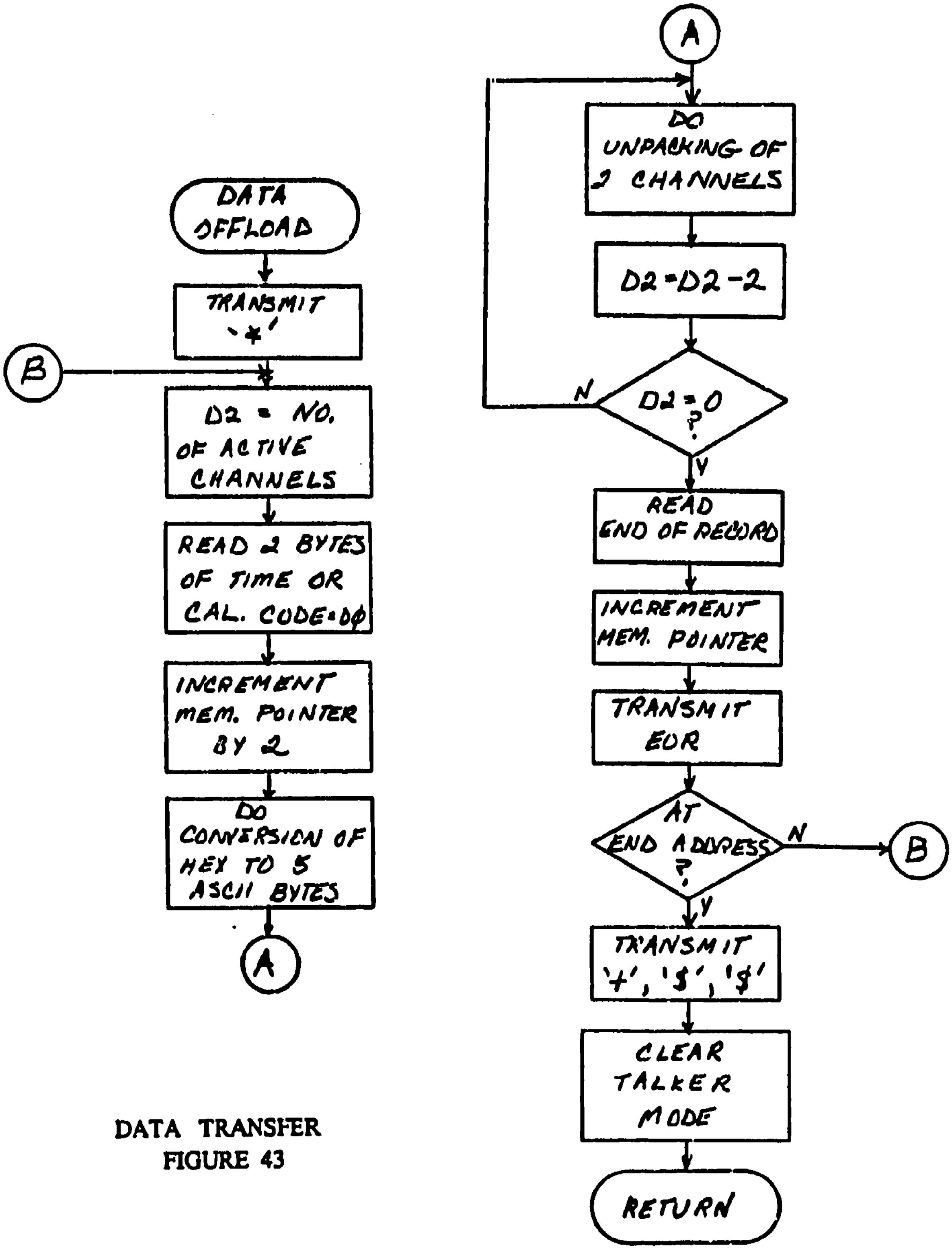
The calibration software as defined in Figure #44 will support both an RCAL or shunt calibration scheme for piezoresistive bridge type transducers, and a voltage substitution mode. The calibration routine will be performed at user defined requests for verification of sensor operation and automatically at pre and post acquisition cycles. In the RCAL mode, the shunt resistors



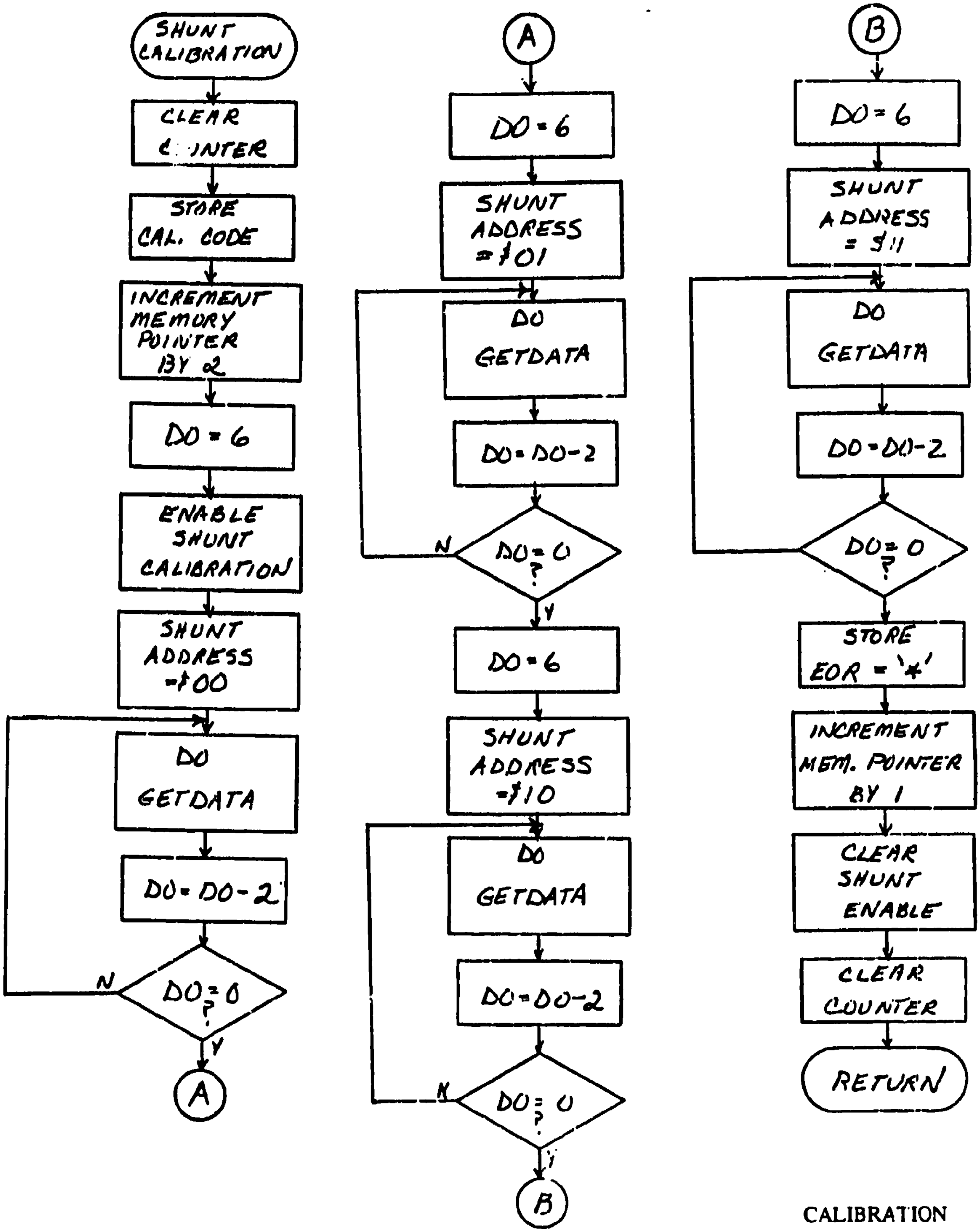
SYSTEM MONITOR
FIGURE 41



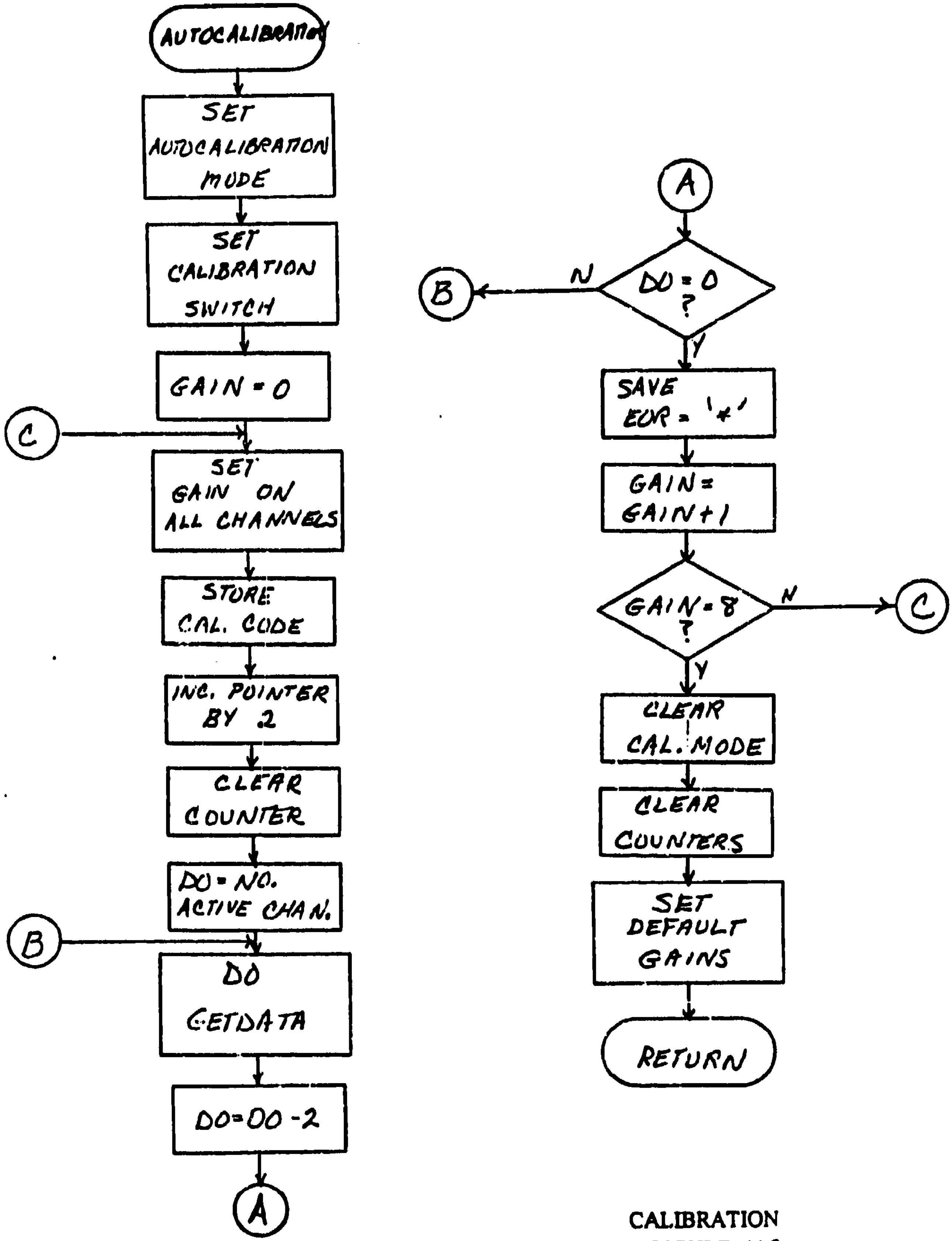
ACQUISITION
FIGURE 42



DATA TRANSFER
FIGURE 43



CALIBRATION
FIGURE 44A



CALIBRATION
FIGURE 44B

RC1-RC12 mounted on the analog signal conditioning module will be switched across the output to the transducer. Sensor output will be collected via the analog and converter path and stored within the DASS-II memory. If this is a requested calibration cycle other than pre or post acquisition, data will be offloaded via the RS232 to the IBM for user review. Upon the completion, the routine will return to the monitor.

2.10.7 Diagnostics

The diagnostics software will be used to evaluate the operational integrity of major components of the DASS-II. The flowchart of Figure #45 outlines the diagnostic tests as follows:

Test RAM Memory
Test Power
Verify Sensor Operation
Verify RS232

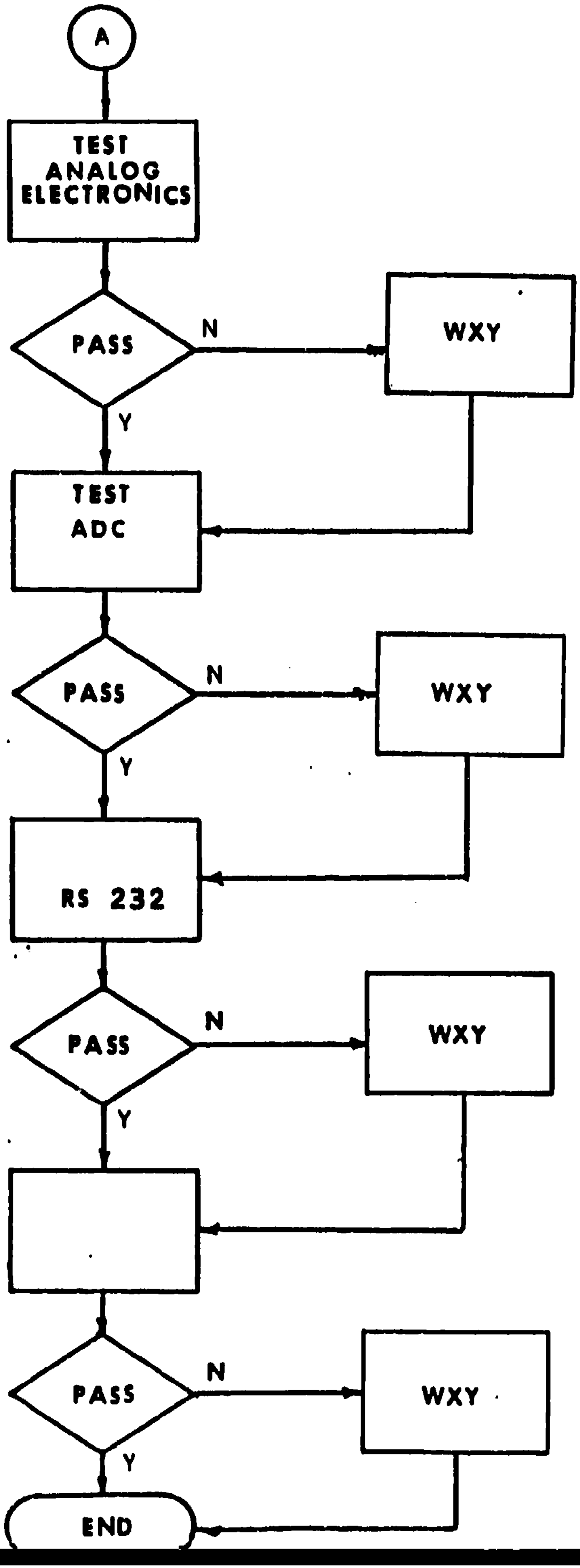
The memory test algorithm is illustrated in Figure #46, where all RAM memory is tested by loading a predetermined test word into each memory location, followed by a read and verification of memory consistency for each location. Each discrepancy is identified and marked. If a maximum error count is exceeded, an error status message is sent to the IBM. If the test passes, a pass status is provided to the DASS.

The power test subroutine illustrated in #47, inputs a power status byte from the power monitor board, decodes the status and sends the appropriate pass/fail status to the IBM. If any of the voltages are not present, the test will be defined as failure status.

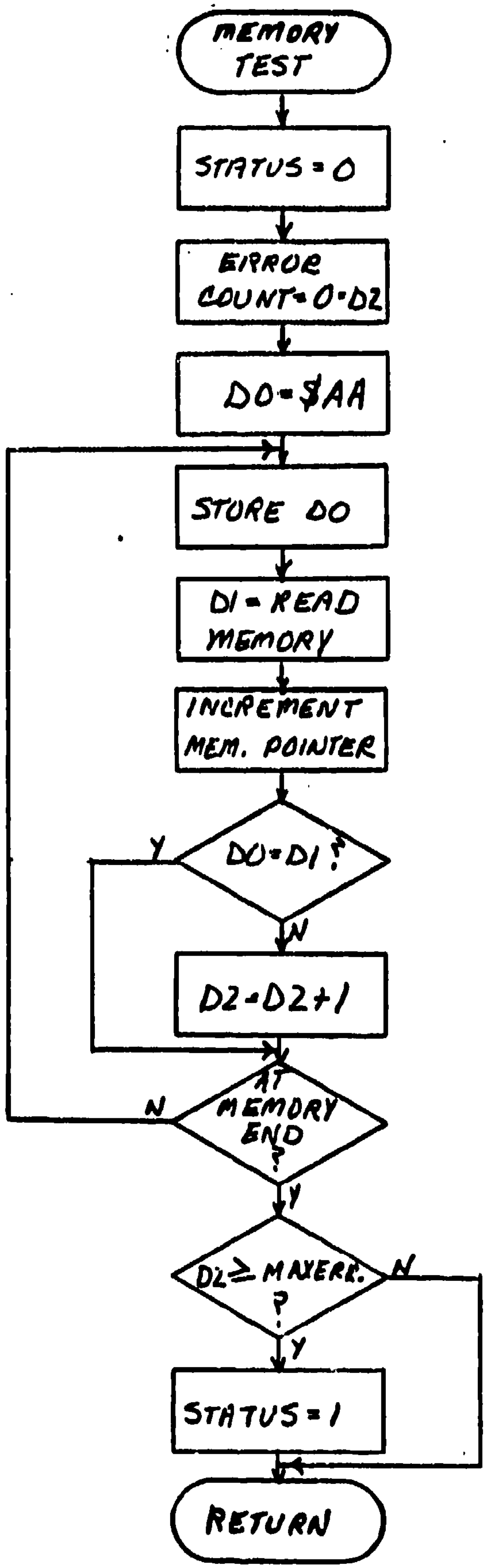
2.11 Power Subsystem

The proposed subsystem provides for system power and regulation circuitry allowing the DASS-II to be powered internally via a custom high density battery configuration or via an external power source. The internal battery modules are all self-contained within the Hybrid III legs and ruggedized to withstand the specified environment. The battery packs will be distributed within the upper thigh, in a star wheel/cylinder housing as illustrated in Figure #48. The assembly will consist of multiple Nickel Cadmium packs dedicated to specific functions, such as DASS-II power, sensor power, e . The use of multiple packs as compared to single large packs with taps a specific voltages has several key advantages. The ability to drain NiCAD batteries (+/- V) equally increases battery life. Rarely, utilizing taps can voltage drain be equalized. Secondly, power management schemes, controlling power to certain system components (i.e. sensors), require dedicated pack arrangements. The multiple pack scheme increases the number of cells, however, at the projected voltage requirements and discrete voltages, it is recommended at this time to consider multiple packs.

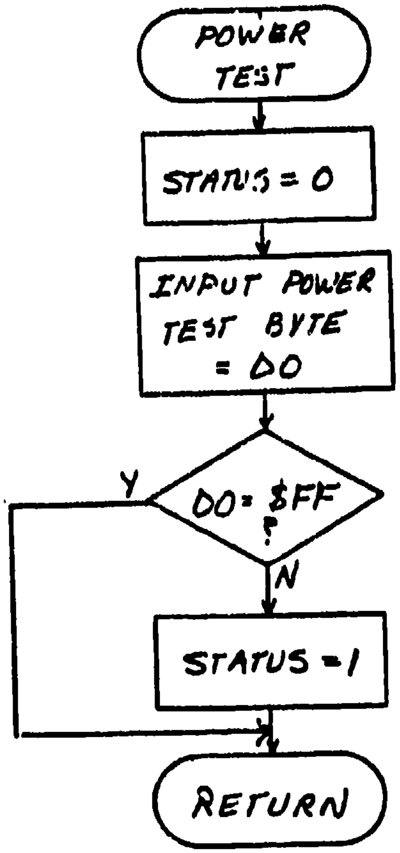
Investigation of various battery types lithium, lead acid, gel acid, etc. have indicated two main problems. One, many of higher density power cells contain corrosive materials which should they be damaged can destroy the DASS-II electronics. The problem with the noncorrosive type of batteries



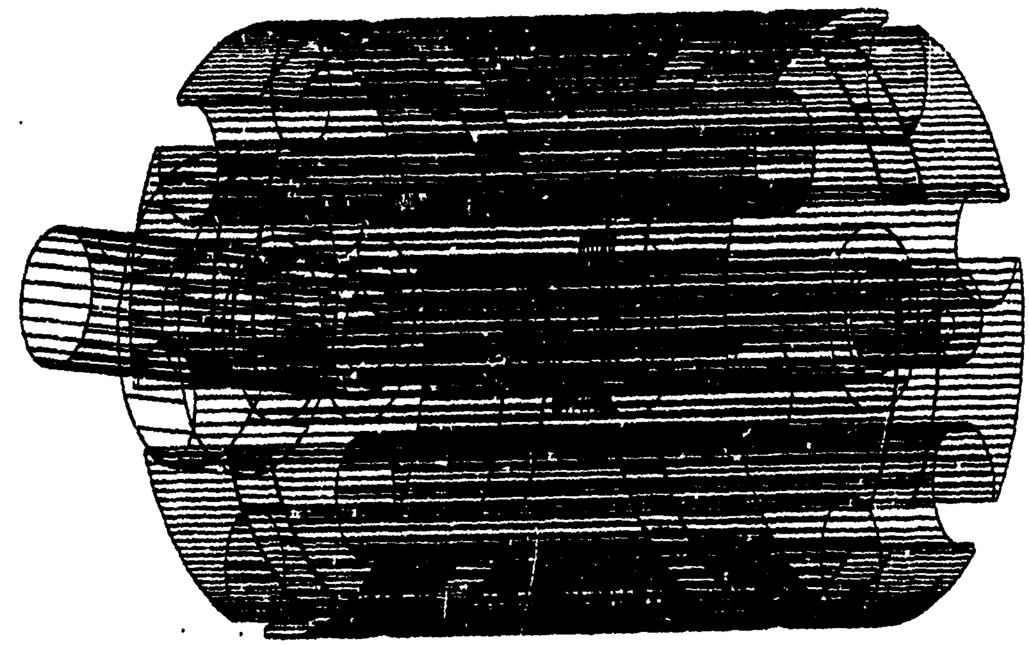
DIAGNOSTICS
FIGURE 45

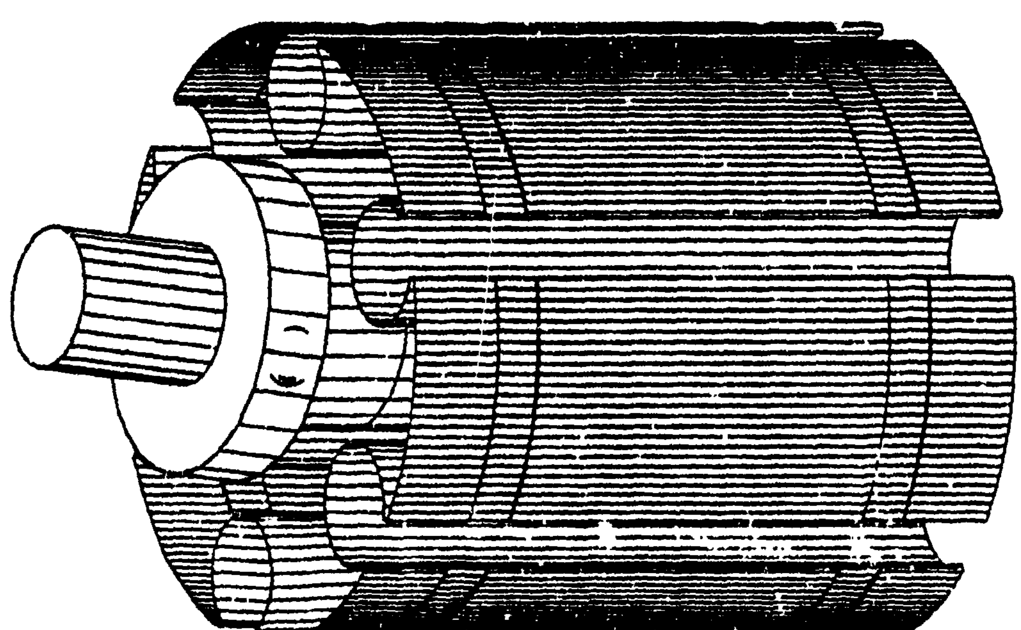


RAM MEMORY TEST
FIGURE 46



POWER TEST
FIGURE 47





POWER SUBSYTEM
FIGURE 48

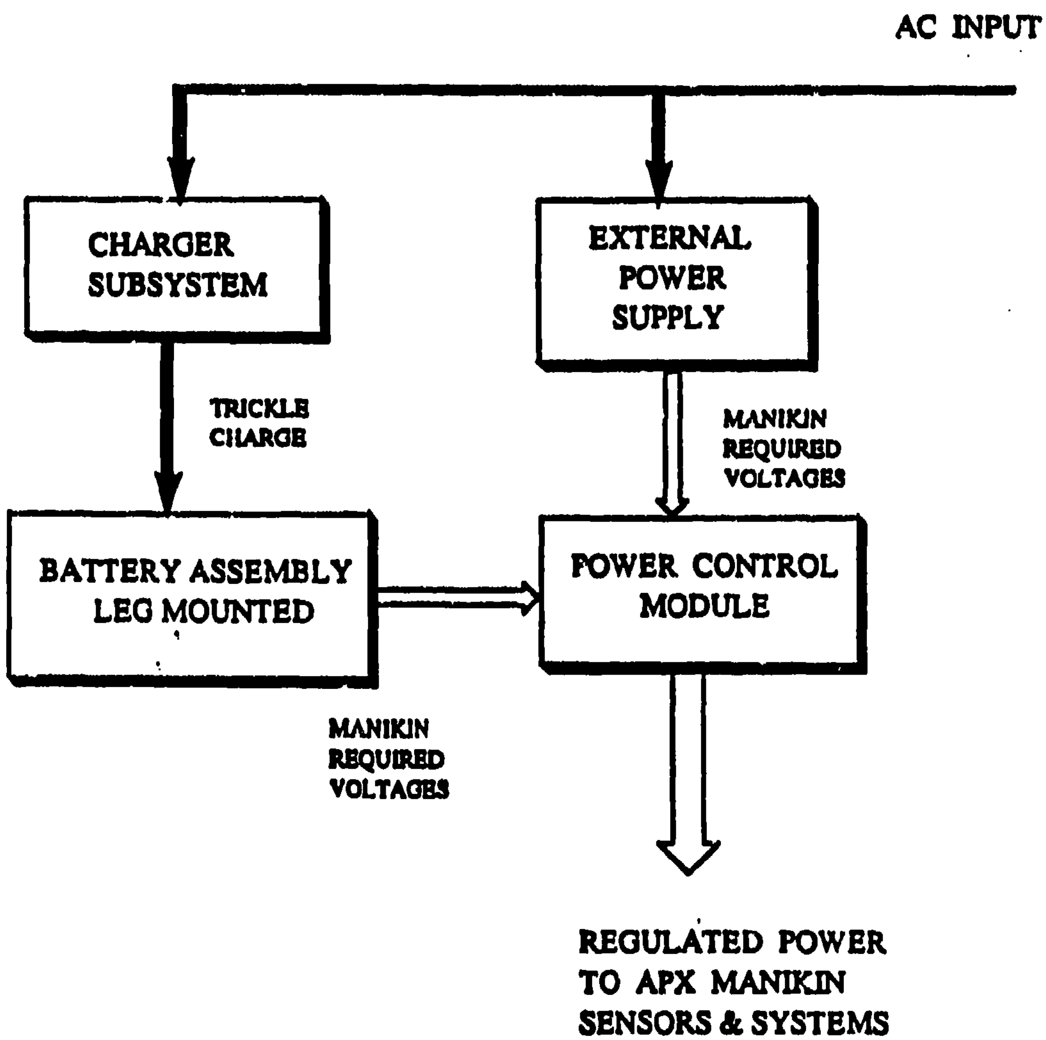
such as the lithium type cells is that they do not provide the output loads necessary to operate the DASS-II and sensors for any significant period of time.

In support of the NiCAD battery packs a power control module will be necessary as illustrated in Figure #49 and detailed in Schematic #4. Shown are the multiple battery packs identified BP1-BP4 interfacing to a control module housing multiple relays R1-R14 and reverse flow limiting diodes. The relays are shown as (NO), normally open or NC, normally closed illustrate battery system operation. In the case of external power operation, the DASS-II will open relays R4-R14 disengaging the batteries. The diodes protect the batteries from possible reverse current flow from the external power source. In the recharge mode, all battery pack grounds must be disconnected from the DASS-II enabling the charging current to flow equally through all the cells. The actual pack sizes and power requirements will be established during phase II, as specific components are defined.

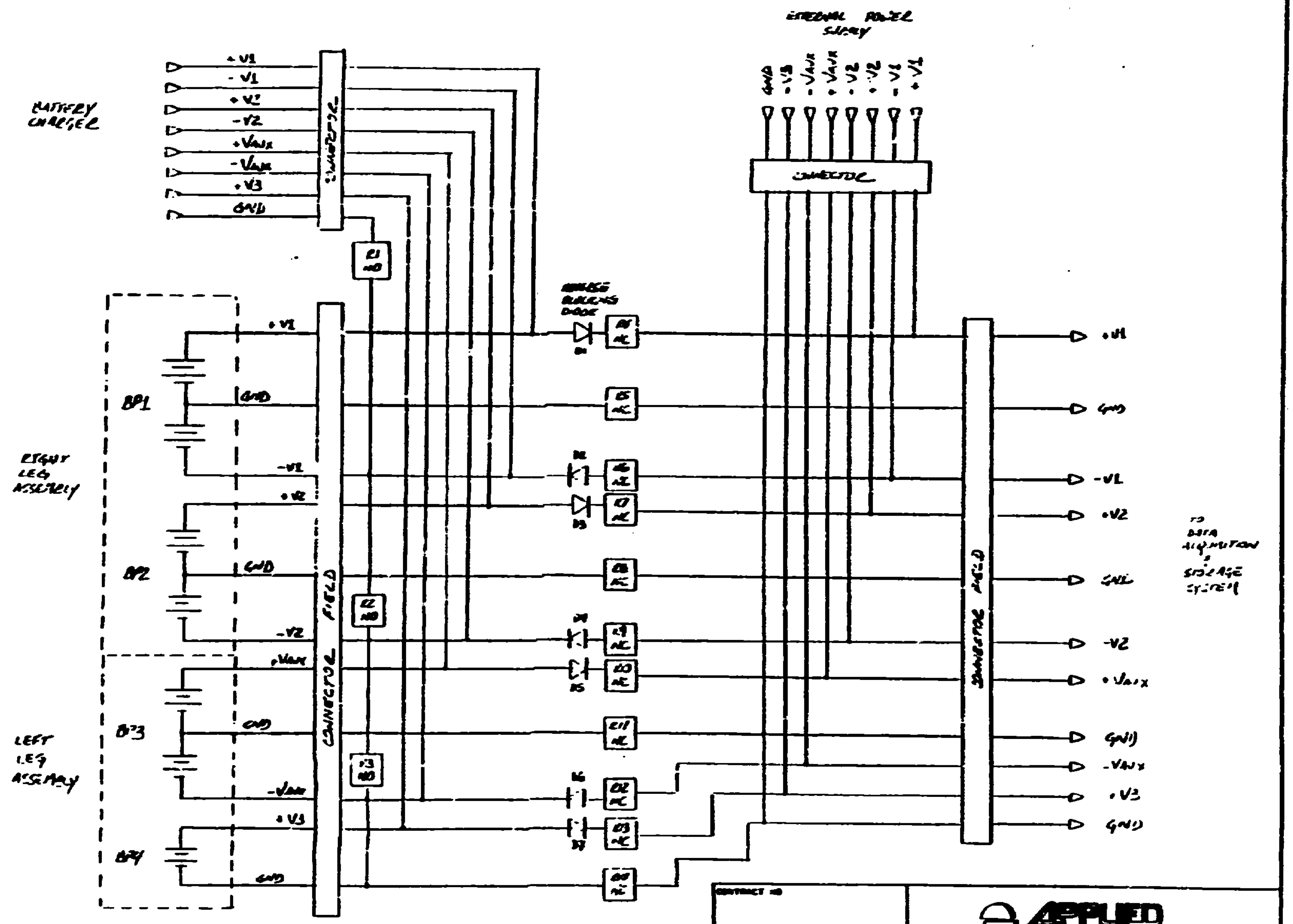
2.12 Support Computer System

The manikin based DASS-II is designed to be integrated into the manikin and accessed through the use of a laptop or portable IBM PC or compatible. This support PC will provide several key functions in the application and utilization of the enhanced manikin system. First, this computer will provide the communication platform and user interface to the DASS-II. All DASS-II functions, such as initialization, calibration, diagnostics and acquisition will be controlled via the user interface. The command structure of sending ASCII codes to initiate operations and signal operation completion. Secondly, the IBM provides the offload media or resource for the DASS-II. Following an experiment, data will be transferred from the DASS-II memory onto the IBM hard disk via the RS232 interface. As was discussed previously, as a alternative the credit card memories will be utilized, requiring a hardware interface on the IBM and driver software to function under DOS. The third function of the IBM is to provide data processing and analysis of the offloaded data. The data transferred will probably be interleaved maximizing DASS-II memory utilization, requiring data to be sorted into individual files, for example a file for each channel and an elapsed time file. The data within these files will be converted to scientific units indicative of the sensor function, utilizing the calibration parameters provided by the manufacturers. The IBM will support graphics, enabling channel data to be displayed for evaluation and review. Beyond the scope of this contract, the IBM can process the channel data into the accelerations, velocities, displacements, attitudes, loads and moments of interest, translate the parameters to the anatomical points of interest, and performance statistical comparisons to various databases to evaluate, response, physiological acceptability and injury mechanisms. It is recommended that the system as outlined in Figure #49, be utilized as a guideline for the IBM support computer. The system provides sufficient capabilities for the required tasks and the future processing task mentioned. The system supports the high resolution graphics and high density disk requirement to satisfy the program needs.

APX MANIKIN POWER SUBSYSTEM



POWER CONTROL MODULE
FIGURE 49



POWER CONTROL MODULE
SCHEMATIC # 4

The Dauphin 2000 Series

A number crunching laptop for the workforce of the 90's

Put the extensive number crunching power of the Dauphin 2000 series to work for you. We can provide the look and feel of a desktop unit in a laptop for financial analysts, accountants, investors and your high-powered sales force.

- Desktop beating performance
- Separate numeric keypad
- Dual-glide screen
- Superb VGA display
- Compact footprint
- Manufactured in the U.S.

Dauphin Technology, Inc. 1125 E. St. Charles Road Lombard, Illinois 60148 708 • 627 • 4004

DAUPHIN 2000 TECHNICAL SPECIFICATIONS

386SX-16 system	386DX-25 system

HIGH PERFORMANCE

386SX-16 system

- Intel™ 386SX 32-bit CPU
- 16 MHz
- Zero wait state (optional)
- 80387SX math co-processor (optional)
- 40 MB hard drive - standard
- 1.44 MB 3-1/2" floppy disk drive
- 2 MB RAM, expandable to 4 MB
- 4 ROM sockets (optional)
- UNIX™, XENIX™ and Windows™ capabilities

386DX-25 system

- Intel™ 386DX 32-bit CPU
- 25 MHz
- 16 K cache memory
- Zero wait state (optional)
- 80387DX math co-processor (optional)
- 40 MB hard drive - standard
- 1.44 MB 3-1/2" floppy disk drive
- 2 MB RAM, expandable to 8 MB
- Auto suspend and resume
- 4 ROM sockets (optional)
- UNIX, XENIX and Windows capabilities

TRUE PORTABILITY

386SX-16 system

- 12 Volt NiCad battery pack
- 3 hours of battery power
- Intelligent power management
- Recharge time of 3 hours
- 96 to 263 Volts AC power / 12 Volts DC power
- 10.5 lbs. without battery; 14.5 lbs. with battery pack
- 14.3" (L) x 12.2" (W) x 3.9" (H)

386DX-25 system

- 12 Volt NiCad battery pack
- 2 hours of battery power
- Intelligent power management
- Recharge time of 3 hours
- 96 to 263 Volts AC power / 12 Volts DC power
- 10.5 lbs. without battery; 14.5 lbs. with battery pack
- 14.3" (L) x 12.2" (W) x 3.9" (H)

USABILITY

386SX-16 system

- 10" (diagonal) pagewhite backlit LCD
- VGA 640 x 480 pixels
- 91 key, full size, full travel keyboard
- Separate numeric keypad
- 12 dedicated function keys

386DX-25 system

- 10" (diagonal) pagewhite backlit LCD
- VGA 640 x 480 pixels
- 91 key, full size, full travel keyboard
- Separate numeric keypad
- 12 dedicated function keys

EXPANDABILITY

386SX-16 system

- 1 parallel and 2 serial ports
- VGA (analog) port
- AT™-compatible external keyboard port
- External floppy drive port
- 100 pin, 16-bit expansion bus

386DX-25 system

- 1 parallel and 2 serial ports
- VGA (analog) external port
- AT™-compatible external keyboard port
- External floppy drive port
- 100 pin, 16-bit expansion bus
- LIM 4.0 support for memory over 1 MB

OPTIONS

386SX-16 system

- 80 MB or 100 MB hard disk drive
- Fax (9600 Baud) / Internal Modem (2400 Baud)
- 4 MB RAM
- 3.5" floppy drive (1.44 MB or 720 KB)
- 5.25" floppy drive (1.2 MB or 360 KB)
- Soft carrying case

386DX-25 system

- 80 MB or 100 MB hard disk drive
- Fax (9600 Baud) / Internal Modem (2400 Baud)
- 4 MB or 8 MB RAM
- 3.5" floppy drive (1.44 MB or 720 KB)
- 5.25" floppy drive (1.2 MB or 360 KB)
- Soft carrying case

SERVICE & SUPPORT

One year warranty
48 hour turn-around service time
Toll-free technical assistance

THIS DEVICE HAS NOT BEEN APPROVED BY THE FEDERAL COMMUNICATIONS COMMISSION. THIS DEVICE IS NOT, AND MAY NOT BE, OFFERED FOR SALE OR LEASE, OR SOLD OR LEASED UNTIL THE APPROVAL OF THE FCC HAS BEEN OBTAINED.

Dauphin Technology, Inc. 1125 E. St. Charles Road Lombard, Illinois 60148 708 • 627 • 4004

2.13 Software

The use interface software will consist to multiple graphic screens detailing and highlighting the operational interface with the DASS-II. The typical proposed operation is outlined as follows:

Upon power up, the main screen, illustrated in Figure #50, comes up while specific parameters are initialized and communications with the DASS-II are established. If communication fails, an error message will be provided to the user, requiring the user to correct the error. The main screen will be followed by the options selection display, illustrated in Figure #51. From this display table, the user selects the desired functions. As in the case of initialization, illustrated in Figure #52, in progress, completion and error messages will be provided. In the case of functions such as calibration and diagnostics, sequential options will be provided as illustrate in Figures #53, and 54. Upon completion of each display function, operation is returned to the previous display segment. In the case of acquisition, the message illustrated in Figure #55, indicates that the IBM will be disconnected from the DASS-II for the experiment. As in previous cases, the data offload procedure will support several options as illustrated in Figure #56. The code to communicate with the DASS-II, generate the user interface displays and display results to the user will be developed at a higher level language such as C or Fortran.

APX BIODYNAMIC MANIKIN

DASS-II

DATA ACQUISITION & STORAGE SYSTEM

APPLIED PHYSICS INC.
31 HIGHVIEW AVE
NANUET, NY 10954

PC USER INTERFACE
MAIN MENU
FIGURE 50

APX BIODYNAMIC MANIKIN

Operational Function:

1: Pretest / Initialization
2: System Calibration
3: Calibration Data Offload
4: Calibration Data Display
5: Diagonostics
6: Acquisition
7: Data Transfer / Offload
8: Modify System Configuration
9: Data Tabular Display
10: Convert / Process Data
11: System Help Files

ENTER FUNCTION SELECTION ---> ____

PC USER INTERFACE
FIGURE 51

APX BIODYNAMIC MANIKIN

SYSTEM INITIALIZATION IN PROGRESS
PLEASE WAIT

DIAGONOSTICS IN PROGRESS

* MEMORY TEST ---> PASS / FAIL
* POWER TEST ---> PASS / FAIL
* SENSOR TEST ---> PASS / FAIL

A: INITIALIZATION COMPLETE

B: SYSTEM INITIALIZATION FAILURE
VERIFY POWER & CABLING, RESET & REINITIALIZE

PC USER INTERFACE
FIGURE 52

APX BIODYNAMIC MANIKIN

CALIBRATION:

1: SENSOR CALIBRATION
2: SYSTEM PATH CALIBRATION
3: CALIBRATION DATA OFFLOAD
4: EXIT

ENTER SELECTION ----> ______

SENSOR CALIBRATION OPTIONS:

1: SELECTIVE CHANNELS
2: ALL CHANNELS
3: EXIT / RETURN

PC USER INTERFACE
FIGURE 53

APX BIODYNAMIC MANIKIN

DIAGONOSTICS:

1: FULL SYSTEM TEST
2: MEMORY TEST
3: POWER TEST
4: SENSOR TEST
5: SIGNAL CONDITIONING TEST
6: EXIT

CAUTION:

FULL SYSTEM TEST AND MEMORY TEST DESTROY MEMORY CONTENTS----- ALL CALIBRATION AND EXPERIMENTAL DATA WILL BE DESTROYED!!!

DO YOU WISH TO CONTINUE ? ---> YES / NO

PC USER INTERFACE
FIGURE 54

APX BIODYNAMIC MANIKIN

ACQUISITION MODE SELECTED:

DISCONNECT ALL UMBILICALS
APX SWITCHING TO INTERNAL POWER
RETURNING TO DOS OPERATION

PC USER INTERFACE
FIGURE 55

APX BIODYNAMIC MANIKIN

DATA TRANSFER / OFFLOAD:

1: SYSTEM DATA / COMMAND DATA
2: CALIBRATION DATA
3: EXPERIMENT DATA
4: EXIT / RETURN

ENTER SELECTION ----> _____

OPTION #1:

SYSTEM DATA TRANSFER IN PROGRESS
PLEASE WAIT

OPTION #2:

CALIBRATION DATA TRANSFER IN PROGRESS

PLEASE WAIT

OPTION #3:

EXPERIMENT DATA TRANSFER OPTIONS:

1: 0.50 SECONDS
2: 1.00 SECONDS
3: 1.50 SECONDS
4: ALL DATA
5: EXIT / RETURN

PC USER INTERFACE
FIGURE 56

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